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ORIGINAL PAPERS

STATISTICAL METHODS IN CERAMIC RESEARCH[1]

BY A. E. R. WESTMAN[2]

ABSTRACT

It is the fundamental object of ceramic research to build up a science of ceramics which will enable us to produce, in the most efficient manner and from a certain group of raw materials, finished products which will have prescribed sets of physical properties. In attempting to reach this objective, it is of importance that we develop new methods of research which are particularly fitted to solve our fundamental problems, and apply, as effectively as possible, the research methods which are now available. These research methods can be divided, on a working basis, into two classes, (1) *exact methods* in which the relationship existing between any two variables is determined by experiments in which the effects of all the other variables are rendered negligible by careful control of the experimental conditions, (2) *statistical methods*, which are used when it is impossible or impracticable to obtain such close control of the experimental conditions or when sampling errors are important and it is possible to repeat the experiments many times. It is the purpose of this paper to draw attention to the fact that we, as ceramists, have almost entirely neglected this second group of methods; to give a brief description, with examples, of some of the modern statistical methods, especially those used by the biometrists; and to point out a few of the situations in which these methods could be used to advantage in ceramic research, especially in investigations of refractory materials.

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[1] Presented at the Annual Meeting, AMERICAN CERAMIC SOCIETY, Detroit, Mich., Feb., 1927. (Refractories Division.) Received January 14, 1927.

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I. Introduction

1. Object of Ceramic Research

The fundamental object of ceramic research is to build up a science of ceramics which will enable us to produce, in the most efficient manner possible and from a certain group of raw materials, finished products which will have certain prescribed sets of physical properties.

The group of raw materials for clay ware are the naturally occurring clays and minerals. It is obvious that the more materials this group includes the easier will be the task of the ceramist; it is also evident that an accurate knowledge of the properties of these materials is vital to our progress. It is for this reason that we find ceramists engaged in developing new raw materials and in studying their properties and methods of purification. This is one of the important steps in achieving the object defined in the previous paragraph.

The finished clay products are produced, in general, by mixing the raw materials in certain proportions, shaping, drying, and firing. A study of these processes is also of great importance and such a study is being made at the present time.

The physical properties desirable in the finished products should, theoretically, be prescribed by the architects, industrial furnace designers, and other users of ceramic products. Actually, in many cases, the users of the ceramic products have refused or neglected to carry out the investigations which are needed to make accurate prescription possible and, for this reason, we find ceramists studying the application of ceramic products, particularly refractories.

In practically all cases, the materials to which they expect finally to apply their results are characterized by their variability and, sooner or later, the question of sampling errors must be faced.

Our ceramic processes are, and probably always will be, characterized by considerable variability, and our finished products are subject to variations in their physical properties which cannot be neglected. It seems unreasonable to expect that we shall ever succeed in making a complete study of these variable materials, processes, and products if we neglect their common characteristic which is their variability. It is still more unreasonable to expect that we shall be able to build up a science which will combine our knowledge of materials, processes and products into generalizations and laws that will enable us to solve the problem stated at the beginning of this paper, as long as we neglect the matter of variability.

These conclusions are borne out by the fact that, although we have a very voluminous literature in which numerous experiments are described and many data are given, we have very few fundamental generalizations. Most of our attempts to review the literature and

arrive at fundamental hypotheses or laws that would form a basis for a ceramic science are met with a mass of contradictory data; in fact, on many questions, contradictions seem to be the rule rather than the exception. The probable reason for a good proportion of these contradictions will be pointed out later.

2. Importance of Research Methods

If we investigate the growth of other sciences, we find that, in nearly all cases, the important developments were preceded by periods in which new methods of research and thought were conceived. It would seem right, therefore, that we should give every consideration to the development of research methods which will be particularly powerful in dealing with our fundamental problems. These research methods and methods of thought should be such that they enable us to state our fundamental problems in definite language and should lead, in a definite manner, to a solution of these problems.

We have already made considerable progress in developing research methods of a certain type and in applying those developed in other sciences. Some of these methods, such as the microscopic and the X-ray methods have produced very important results and have made it possible to understand a number of reactions which before were shrouded in mystery. We have made good use of the methods of analysis of the chemist and have applied the exact methods of the physicist in determining the properties of our raw materials and products. Nearly all of these methods are what might be called "exact methods". They involve experiments which are carried out with pure materials under nearly ideal conditions, experiments in which only one or two of the factors are allowed to vary, the remainder being controlled so that their effect is negligible.

3. Limited Applicability of Exact Methods

Although these exact methods have provided us with some very definite conceptions and with definite starting points for other experiments, it seems improbable that they will, in a reasonable time, provide us with a complete solution for our problems, because a study of our raw materials, processes and finished products necessarily involves the study of a great number of variables. Besides phase-rule relations in which a large number of components are involved, we have also to consider the effect of particle-size, rates of reaction, fluctuations in temperature, partially attained thermodynamic equilibrium, relative position and degree of dispersion of the phases in space and a number of other factors which can readily be listed. Unless the exact methods produce some revolutionary discoveries that radically change the nature of our raw materials and manufacturing processes, it seems improbable that they, alone, will provide a solution for our problem.

The ceramist, therefore, must develop or borrow methods which will enable him to obtain reliable information from experiments in which it is impossible to control many of the factors.

4. Statistical Methods

Some years ago, the biologist, particularly the biometrist, found himself faced with almost the same situation as is described in the previous paragraphs. He was forced to carry out experiments with such variable objects as guinea pigs and rats and to analyze data collected from large groups of men, who, as we can easily realize, differ from each other in a great many ways. The number of factors influencing any one of his results was very great and exact methods proved quite inadequate.

It is a matter of importance to the ceramist that the biometrist has succeeded, to a surprising extent, in overcoming the difficulties inherent in such a situation and has developed methods of research and thought which have enabled him to get significant results from his experiments and his collections of data. These methods are being introduced into engineering research with very gratifying results, as is evidenced by the work of Shewhart,[1] and Gowan, Leavitt, and Evans.[2]

It is the purpose of this paper to describe briefly some of these methods and to point out how they can be used in ceramic research in securing more definite statements of our problems, in planning our experiments so they will give more significant results and in analyzing our data so that the results can be stated in a more definite form, thus avoiding contradictions.

We shall group these methods of research under the general heading of "statistical methods" which will be used to distinguish them from the "exact methods" previously discussed, although from one viewpoint the difference is only one of degree. We shall consider that statistical methods involve experiments in which we can observe the occurrence of various possible contributory causes of a phenomenon but cannot control them, and that exact or classical methods involve experiments in which all the possible contributory causes are controlled, or their effect is carefully measured and the values obtained from the experiments corrected accordingly. The remainder of this paper will be devoted to a discussion of statistical methods, so defined.

II. Description of Statistical Concepts and Methods

5. Concepts

The primary statistical concept is that of a "population." A population is a large group of individuals; its essential

[1] *Bell System Tech. Jour.*, **3**, No. 1 Jan. (1924); *Ibid.*, **5**, No. 1 Jan. (1926); *Ibid.*, **5**, No. **2**, April (1926); *Ibid.*, **5**, No. 4, Oct. (1926).

[2] Maine Technology Experiment Station, *Bull.*, Nos. 5–17, Univ. of Maine, Orono, Maine. Proc. National Academy of Sciences, II, 1, pp. 11–16, Jan. (1925). *Proc. A.S T.M.*, **25** [2], 218–27 (1925).

characteristic is that it should be capable of exact definition. Although the use of the word "population" ordinarily implies that the individuals are people, there is no such restriction to its use in statistical work. For instance, we may have a population consisting of all the people of school age living in a certain community at a certain time, or a population consisting of all the brands of fire brick manufactured in the United States during a certain year, or a population of all the experimental values of a certain quantity which would be obtained if a certain experiment were to be repeated a large number of times.

The first step in an investigation is to define, as accurately as possible, the population which is to be investigated; the next step is to specify the characteristic or property which is possessed in varying degrees by the different members of the population, and with which the investigation is concerned. This quantity is usually called a "variate".

In the populations mentioned in the preceding paragraphs we might take as variates the heights of the population of people, or the transverse strengths of the population of brands of fire brick, or the magnitudes of the experimental values. Sometimes we wish to investigate the possible relationships existing between two variates in the same population, *e.g.*, the heights and weights of the people, the porosities and transverse strengths of the fire brick, or the magnitudes of the experimental values and the times at which they were made.

Since the statistician usually cannot deal with the whole of the population he is investigating, in fact it nearly always, at least theoretically, consists of an infinite number of individuals, he selects a random sample. This consists of a manageable number of individuals of the population selected in such a way that, at each selection, every member of the population has the same chance of being chosen. For instance, in obtaining a random sample of the fire brick manufactured in Missouri during a certain year, it would not do to select a number of brands of brick at random, as the brick of some brands are produced in much larger quantities than those of other brands and the fire brick has been specified as an individual and not the brand. In the same way, in order to secure a random sample of a population of experimental values, it is necessary that their magnitudes be not dependent on the times at which they are obtained.

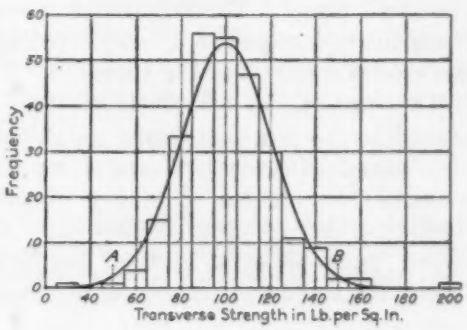

FIG. 1.

From measurements performed on the sample, the statistician calculates a number of "statistics", a statistic being a value calculated from an observed sample with a view to characterizing the population from which it is drawn. The arithmetic mean and the standard deviation are examples of such quantities. Having calculated a sufficient number of statistics to characterize the population as accurately as his methods of measurement and conditions of sampling warrant, the next step is to estimate the magnitude and nature of the errors to which they are subject. These include estimates of "goodness of fit" and "significance," quantities which will be discussed later.

6. Frequency Distributions The data which are secured from a sample are usually presented in the form of a "frequency distribution", which specifies how frequently the variate takes each of its possible values. Such data is usually plotted in the form of a "histogram." In making a histogram, a horizontal scale of variates is laid out; rectangles are then erected in such a way that the area of each rectangle indicates the number of individuals of the sample which were found to have values of the variate between the two values given by the intersection of the sides of the rectangle and the horizontal scale. If an individual is found to have a value of the variate exactly equal to one of these partition values, it is considered equivalent to two half-individuals, one of which has a value of the variate immediately above, and the other immediately below, this partition value. In case the scale of the variate is uniform and the widths of the rectangles equal, the areas of the rectangles will be proportional to their heights and a perpendicular scale of frequencies can be set up.

Figure 1 shows a histogram which was plotted from data secured from measurements of the transverse strengths of 270 fireclay brick. The variate considered was the transverse strength each brick would have if the mean value for its brand were 100 lbs. per sq. in. For the purpose of illustration we shall consider that all the brick belonged to the same brand. The population would then be all the brick of this brand manufactured in a certain period during which their properties were not a function of the time.

The statistician characterizes the frequency distribution represented by such a histogram by calculating the "arithmetic mean", the "standard deviation" and other statistics. The arithmetic mean expresses the central tendency of the measurements, the standard deviation the amount of dispersion or spread. Sometimes the so-called "probable error" is used instead of the standard deviation, and, lately, the square of the standard deviation or the variance is coming into common use.

In the example shown in Fig. 1, the arithmetic mean is approximately 100, the standard deviation is approximately ± 20, or plus or minus the value represented by the width of two of the rectangles, or two class intervals. The standard deviation of a distribution calculated as a percentage of the mean value is called the coefficient of variation and is a useful measure of the variability or lack of uniformity of the population.

From calculations based on these or on other parameters or statistics, the statistician finds an equation which can be used to express the frequency distribution. In Fig. 1, for instance, the full line curve is plotted from the equation

$$y = \frac{N}{\sqrt{2\pi}\,\sigma}\, e^{-x^2/2\sigma^2}$$

in which y is the frequency, N the number of measurements (270), σ is the standard deviation and x is the deviation of the variate from the mean value. The standard deviation σ and the deviation x should be measured in the same units. This is a curve of the normal type. Curves of this type fit a large number of the frequency distributions found in biometric work and will very likely fit a good proportion of the distributions found in ceramic research. In some cases other types must be used. Standard procedures for determining which types to use and how to calculate them have been developed by Charlier,[1] Pearson[2] and others.

The question then arises, how accurately do these statistics calculated from measurements made on the sample characterize the population from which it was drawn. It is in this direction that the modern statisticians led by Karl Pearson[2] "Student",[3] and others have made their most significant advances. These have resulted in the such theories as the theory of Goodness of Fit and the theory of Small Samples, both of which are of importance to the research worker in ceramics.

In the case we have been considering, for instance, if we assume that our sample of 270 bricks is a true random sample from a population having normally distributed transverse strengths, on the basis of the

[1] For a discussion of Charlier's method see The Mathematical Theory of Probabilities and Its Application to Frequency Curves and Statistical Methods, Arne Fisher, Vol. I, New York, 1915.

[2] Karl Pearson, Galton Professor, University of London, author of many articles in *Biometrika*, For curve-fitting see Frequency Curves and Correlation, W. Palin Elderton; C. and E. Layton, London, 1906. See also Tables for Statisticians and Biometricians, edited by Karl Pearson, issued by the Biometric Laboratory, University of London.

[3] *Biometrika*, **6**, 1–15, (1908); *ibid.*, **9**, 416–417, (1917).

goodness-of-fit theory we would expect a fit between the theoretical curve and the actual frequency distribution as poor or poorer than that shown in Fig. 1 about 58 times in 100 trials, the frequencies for deviations greater than 50 (below A, above B, Fig. 1) being lumped together because the theory can proceed by fractions of a brick whereas the data cannot. Statistical theory also enables us to decide what is the significance of the mean value calculated from such a sample, as well as the significance of the standard deviation and other statistics.

7. Correlation, Multiple Correlation

Very frequently the statistician wishes to investigate possible relationships which may exist between two variates of a population, rather than to study just one variate. A study of the relationship between two variates of a population is called a study in "correlation"; a study of three or more variates is called a study in "multiple correlation." The term "skew correlation" is used when the values of variates taken separately, are not distributed normally. This latter type of correlation has been investigated by Karl Pearson[2] and others.

In a normal correlation study, a random sample is obtained from the population; measurements of the values of the two variates are made on each individual, thus yielding as many pairs of corresponding values as there are individuals in the sample; a correlation table is prepared and a correlation coefficient calculated.

Figure 2 shows a typical correlation table. The population in this case was a certain brand of stiff-mud fireclay brick; the variates considered were the average lengths of the faces first measured and the lengths of the opposite faces, two measurements of each face being made. We shall call these the X- and Y-variates respectively. Measurements were made on 289 bricks, using rules graduated in thirty-seconds of an inch. The table consists of a number of columns and rows. Each row is labelled at the left with a number giving a value of the Y-variate, the columns are similarly labelled at the top with numbers giving values of the X-variate. Each of the numbers entered in the table indicates the number of bricks having a Y-variate value indicated by the row in which the number is placed and an X-variate value indicated by the column in which it is situated. Thus, the number 28 near the center of the table records the fact that, for 28 of the brick, the average length of the face first measured was 8 inches $+\frac{27}{32}$, while the average length of the opposite face was 8 inches plus $\frac{28}{32}$. The fractional values occurring in the table are due to the treatment of the partition values by the method discussed in section 6. The

Length of First Face, X increasing ---->

Length of Opposite Face, Y increasing ---->

	25	26	27	28	29	30	31	f_y
25								
26	$\frac{1}{2}$	2	$6\frac{1}{2}$	4				13
27	1	$6\frac{1}{4}$	$28\frac{3}{4}$	$17\frac{1}{4}$	$\frac{1}{4}$			54
28		$2\frac{1}{4}$	28	72	14	$1\frac{1}{4}$	$\frac{1}{2}$	118
29			$3\frac{3}{4}$	18	$38\frac{1}{2}$	7	$1\frac{1}{4}$	$68\frac{1}{2}$
30				$1\frac{3}{4}$	6	20	$2\frac{1}{4}$	30
31					$\frac{1}{4}$	$4\frac{3}{4}$	$\frac{1}{2}$	$5\frac{1}{2}$
f_x	$\frac{1}{2}$	$10\frac{1}{2}$	67	113	$59\frac{1}{2}$	33	$4\frac{1}{2}$	289

FIG. 2.

sums of the columns are shown at the bottom of the table and give the frequency distribution of the X-variate, the sums of the rows or arrays are shown at the right and give the frequency distribution of the Y-variate. In the case considered these distributions are approximately normal.

An examination of the table shows that low values of the X-variate tend to be associated with low values of the Y-variate and that high values of the X-variate are associated with high values of the Y-variate. To express this relationship in quantitative fashion, the statistician calculates a statistic known as a "correlation coefficient". This can have absolute values between zero and one and can be either positive or negative. In the above example the correlation is positive. If high values of the X-variate were associated with low values of the Y-variate, etc., the correlation coefficient would be negative. A correlation coefficient of value unity indicates absolute dependence between the two variates or indicates that they can be considered as the same variate, a correlation coefficient of value zero indicates that they are independent and intermediate values of the coefficient indicate degrees of correlation between these two extremes. In the example shown in Fig. 2 the correlation coefficient has a value $+0.71$ which indicates a high correlation a result which is to be expected. Correlation coefficients can be calculated from data given in correlation tables very readily by methods given in most of the modern books on statistics.

When dealing with partial correlation, the object of the investigation is generally to find what degree of correlation would exist between the values of two of the variates if the effects of the other variates were removed. This is accomplished by calculating statistics known as "partial correlation coefficients," using methods developed by Karl Pearson[1] and others.

8. Contingency It sometimes happens that the values of the variates under investigation cannot be expressed numerically. Such would be the case, for instance, in a study of the relationship existing between the color of a number of fire brick and the colors of the clays from which they were made. Studies of this nature are called studies in "contingency" and methods have been developed for calculating contingency coefficients which are analagous to the correlation coefficients described in the previous section.

9. Significance Questions as to the accuracy with which the statistics calculated from measurements of a random sample characterize the population from which the sample is drawn, are constantly arising in statistical investigations. These are questions

[1] *Loc. cit.*

in "significance." Methods of determining the significance of the commonly used statistics have been developed in recent years. Thus, the significance of arithmetic means, differences or sums of arithmetic means, standard deviations, correlation coefficients, theoretical frequency distributions, etc., can now be calculated.

Of special interest, in this connection, are the methods for determining "goodness of fit" which have been developed by Karl Pearson[1] and the Small Sample Theory due to "Student". The former enables us, on the basis of certain assumptions, to calculate how frequently we should expect a fit between a theoretical equation and the data it is supposed to represent, as poor or poorer than the fit actually found, (see sect. 6); the latter enables us to calculate the significance of statistics calculated from small samples, when the information afforded by the sample is the only information available. The Small Sample Theory is particularly useful when, in the cases where one variate is considered, we have to deal with samples of less than thirty individuals and, in cases where two variates are considered, we have to deal with samples of less than one hundred individuals.

III. Application to Ceramic Research

10. Purpose In the foregoing discussion purely illustrative examples have been given. The importance of statistical methods may be better realized if a few situations in which statistical methods are of practical use are considered. The following sections will be devoted to such a consideration, the examples being classified for convenience according to the number of variates considered, the last section being devoted to examples of the use of theories of significance.

11. Problems Involving One Variate The general custom of speaking of the "transverse strength" of a certain brand of brick often blinds us to the fact that we are really talking about a variate of a large population of brick which may have very different values for different individuals of the population. Thus, when we wish to determine the "transverse strength" of a certain brand of brick, we ordinarily determine the strengths of a number of individual brick of that brand (generally too small a number) and then calculate the arithmetic mean of these strengths. However, if we realize that we are, in reality, dealing with statistical quantities and study the frequency distribution of the transverse strengths of the bricks (see Fig. 1) it soon becomes apparent that we have calculated only one statistic of the many that might be calculated and have neglected some that are quite important. For instance, the standard

[1] *Loc. cit.*

deviation, which is a measure of the variability of the strengths, is an important statistic which is frequently neglected. There are many situations in which two brands of brick having equal mean strengths but different standard deviations would give very different results in service, *e.g.*, in paving roads. In other cases statistics expressing the "skewness" of the distribution might be of importance.

Again, in industries where uniformity of product is of great importance, *e.g.*, the abrasive industry, a study of the frequency distributions of the properties of the products often provides a very effective means of control. A significant change in the form of one of the distributions would be a very good indication that some significant change in the raw materials or the process had occurred and should be investigated.[1] It is also possible to determine by statistical methods how often samples of the product should be taken in order to control its properties within certain prescribed limits.

12. Problems Involving Two Variates

The method of correlation can be applied quite successfully in a surprising number of situations which otherwise are very distinct. Thus, there are many quantities in ceramic work which can be used as X- and Y-variates in correlation calculations similar to that illustrated by Fig. 2. The method of correlation has given a new importance to observational data obtained from experiments in which various contributory causes of a phenomenon can be observed but cannot be controlled.

One of its most useful applications in ceramic research, especially refractories research, is in the evaluation of laboratory tests. The final evaluation of a laboratory test should be made by determining the degree of correlation which exists between the values secured from random samples by means of the test in question and the values derived from service tests of the same individuals under actual industrial conditions. This degree of correlation may be expressed by means of the correlation coefficient or by the increase in the precision with which we can predict the service value of an individual when we know the value for that individual given by the laboratory test. The ratio between the standard deviation of the service values predicted by means of the information given by the laboratory tests and of the service value predicted without using this information is given by the expression $\sqrt{1-r^2}$, where r is the correlation coefficient between values given by the service and the laboratory tests.

It is interesting in this connection to point out that if, in the example shown in Fig. 2, only two or three of the brick had been measured, the relationship which is evident when large numbers are measured

[1] *Bell System Tech. Jour., loc. cit.*

might quite easily have been missed, no matter how accurately the measurements might have been made. It is, indeed, quite possible that a contradiction of this general relationship might have been obtained. When this is realized, it will be evident that attempts to accredit or discredit a laboratory test by experiments with only two or three brands of brick are quite futile.

In ceramic research we frequently have occasion to apply formulas based on the assumption of homogeneity of structure to materials which are far from homogeneous. It is possible, by correlation methods, to determine in any given case, to what extent this procedure is justifiable. For instance, if the formula is one of the many used for correcting our experimental values for variations in the dimensions of the specimens used, its use can be considered justifiable if a significant correlation is found to exist between the dimensions of the specimens and the uncorrected values and if the correlation between the dimensions and corrected values is very much less or is insignificant.

13. Problems Involving Three or More Variates

Problems involving more than two variates are frequently met in ceramic research. A large number of these problems can be solved if enough data to calculate the important partial correlation coefficients are available. The following example will illustrate this.

Let us suppose that a random sample of brands of fire brick has been selected from a large population of such brands and the values of the following normally distributed variates for the individuals of the sample have been ascertained: (1) the percentage by volume lost in a slag erosion test, (2) the permeability, (3) the porosity. The correlation coefficient between variates 1 and 2, which we shall call r_{12}, is found to be $+0.80$. We might, on this basis, conclude that the permeability determined to a considerable extent the rate at which the slag dissolved the brick. It is known, however, that, on the whole, the more permeable brick are the more porous. Since, to effect the same percentage volume loss, the slag would have to dissolve less actual material in a porous brick than in a dense brick, it might be argued that the high correlation between slagging and permeability was due to the variations in the porosities of the brick and is not really significant. The validity of this argument can be determined by finding the three correlation coefficients obtained by taking the variates two at a time, which we shall call r_{12}, r_{23}, and r_{13} and calculating, from them, the "partial" correlation coefficient for the first and second variate, $r_{12.3}$. The value of this partial correlation coefficient indicates the degree of correlation which would exist between the permeability and slagging values for individuals of a population, all of which had equal porosities. If, for instance, r_{23} had a value $+0.50$ and r_{13} a value $+0.30$, we would find that $r_{12.3}$ had a value

+0.79, and conclude that the high correlation between the permeability and slagging values was not caused by the variation in porosity of the brick.

14. Significance As was pointed out in section (9), the significance of a statistic calculated from measurements on individuals of a sample is a measure of the accuracy with which the statistic characterizes the population from which the sample was drawn. It is generally expressed by means of a probability. Thus, the significance for the value for the difference between the means of two samples may be shown by giving the probability that differences of the same magnitude would arise from random sampling of a single normal population, a low probability indicating a high significance and vice versa. When it is known that the distribution of the statistic in question is normal, or nearly so, its significance may be indicated by giving its "probable error," standard deviation, or variance.

A knowledge of methods for estimating significance can be of great use to a research ceramist in three ways: it will enable him to estimate the significance of the values he has obtained from a series of experiments, it will enable him to design future experiments so that they will yield values of high significance, and it will enable him to estimate the efficacy of such design. An example of the use of the Goodness of Fit Theory has been given in section 6; an example of the use of "Student's" Small Sample Theory, modeled after an example given by "Student" in his original paper, follows.

Let us suppose that the lengths of ten fire brick have been measured and that the numbers of thirty-seconds of an inch by which they exceed or fall short of standard dimensions have been recorded, giving the values shown in column 2 of Table I. Let us suppose, further, that the brick are then subjected to a certain heat treatment and measured, as before, giving the values shown in column 3 of the same table. The differences are shown in column 4. The average difference is +1.58. When its

TABLE I

Brick number	Deviations from standard dimensions (32nd in.) Before treatment	After treatment	Differences
1	2	3	4
1	+0.7	+1.9	+1.2
2	−1.6	+0.8	+2.4
3	−0.2	+1.1	+1.3
4	−1.2	+0.1	+1.3
5	−0.1	−0.1	0.0
6	+3.4	+4.4	+1.0
7	+3.7	+5.5	+1.8
8	+0.8	+1.6	+0.8
9	0.0	+4.6	+4.6
10	+2.0	+3.4	+1.4
Mean	+0.75	+2.33	+1.58

significance is calculated by the Small Sample Theory, it is found that the probability of differences of this magnitude arising by chance is given by the equation $P = 0.003$, or in other words we would expect differences of this magnitude by chance only three times in a thousand trials. It is therefore quite significant.

In some cases the significance of a statistic is of more importance than its magnitude, as the following example, modeled after that given by Fisher[1], will show. Let us suppose that duplicate experiments to determine the effect of a certain treatment on the strengths of fire brick show increases in strength of 8% and 9%, or a mean increase of 8.5%. Similar duplicate experiments to determine the effect of a different treatment show increases of 8% and 18%, or a mean increase of 13%. From this it might be concluded that the second treatment was more effective, causing a mean increase of 13% as compared with 8.5% for the first treatment. However, if we determine the significance of these mean increases by means of "Student's" theory, we find that we would expect mean changes in strength of 8.5% for the first treatment to arise by chance about four times in one hundred trials, whereas we would expect mean changes in strength of 13% for the second treatment to arise about twenty-three times in one hundred trials. The mean change in strength due to the first treatment is, therefore, much more significant than that due to the second treatment.

A knowledge of methods for calculating significance will enable us to conduct our investigations so that the results will have more meaning. For instance, we shall be able to decide whether or not we have used a large enough sample to secure a good significance for values obtained by measurements of the sample. Most ceramists are accustomed to make their experiments in duplicate but very few realize that experiments in triplicate would enable them to detect, with the same degree of significance, differences one-seventh of those detected by duplicate experiments. The practice of deciding on the merits of a number of different brands of fire brick by means of experiments in which only two bricks of each brand are used will be short-lived if methods of estimating significance are widely known. The futility of designing standard tests in which an arbitrary small sample is specified and no provision made for determining the significance of the results will also be realized when the Theory of Small Samples is understood.

The usefulness of statistical reasoning in planning research can be shown by referring again to the data given in Table I. Let us suppose that, instead of measuring the same brick before and after the heat treatment, we had used a different sample in each case. We would then

[1] Statistical Methods for Research Workers, R. A. Fisher; Oliver and Boyd, London, 1925.

have to base our calculations on the mean values +0.75 and +2.33 and consider +1.58 as the difference between two means. The significance of this difference calculated from the Small Sample Theory would then be given by $P=0.08$, which means that we would expect such a difference by chance about eight times out of one hundred trials, as compared with three times in one thousand trials when the same brick were used in both measurements. A value obtained in this way would, therefore, have almost no significance, whereas that obtained by using the same brick in both measurements would have a high significance. The difference is due to the fact that there is some correlation between the values in columns 2 and 3 ($r=+0.8$), or, in other words, our experiment is better controlled when we use the same brick in each measurement. This shows the value of design in such experiments and that we can calculate the efficacy of such design.

There are many ways in which we could get better control in our refractories investigations. The development of methods for measuring the more important physical properties of the individuals of our samples without spoiling them for further tests would help. Another suggestion would be for some central agency, such as the Bureau of Standards, to secure very large numbers of brick of about three different types made under closely controlled conditions. The properties of random samples of these brick could be determined accurately and, on request, random samples could be sent to different laboratories which were carrying on research on refractories. In this way most of our tests could be made on a comparative basis, the differences between the unknown brands and the standard bricks being measured, and disturbing effects due to differences in procedure and furnace conditions minimized.

IV. Summary

From what has been said, it appears that we can consider our fundamental problem to be a problem in correlation involving a large number of variates, that most of our minor problems can be stated definitely in statistical language, that statistical theory in many cases indicates fruitful methods of attack and that an appreciation of the theories of significance would go a long way toward preventing contradictions in the conclusions drawn from our data. It would appear, therefore, that we can consider statistical methods to be powerful methods of attack in ceramic research.

SOME WHITEWARE BODIES DEVELOPED AT THE OHIO STATE UNIVERSITY[1]

By Arthur S. Watts

ABSTRACT

Formulas of bodies and glazes are given which through 10 years of classroom experimenting have proved the best for statuary, electrical, hotel, and chemical porcelain. The conditions and limits of use of carbonates of magnesia and calcium are given.

The following bodies have been developed as the result of repeated class studies over a period of ten years in the Ceramic Department and are presented here in the hope that they may assist others who may be seeking data of this nature as well as to make them permanent records.

Porcelain Statuary Body at Cone 9

Canadian feldspar	37½ %
Florida kaolin	45
Whiting	1
Calcine	16½
	100

Calcine Cone 6

45 % Canadian feldspar
55 % Florida kaolin

This body casts well without salt additions and fires to a fine white color with a good satin surface.

Electrical Porcelain—Cone 12 Single Fire Body

Canadian feldspar	24		Water content	26
Kentucky ball clay	35		Drying shrinkage	4.4
Georgia kaolin	18		Total shrinkage	15.0
Whiting	2		Absorption on 1 hr. boiling	0.06
Flint	21			
Glazed with:				
0.2 K_2O				
0.4 CaO				
0.3 ZnO	0.5 Al_2O_3	4.0 SiO_2	22½ ozs. per pint	
0.05 BaO		0.1 B_2O_3		
0.05 MgO				

Vitreous Hotel China—Cone 10 Biscuit

Biscuited at Cone 10			
Potash feldspar	13.00	Water to mold	31
Soda feldspar	3.00	Drying shrinkage	2.5
Whiting	0.833	Total shrinkage	11.0
Magnesium carbonate	0.833	Absorption after 2 hrs. boiling	0.9
Ball clay	10.00		
Florida kaolin	12.50		
English china clay	22.50		
Flint	37.334		

[1] Presented at the Annual Meeting, American Ceramic Society, Detroit, Mich., Feb., 1927. (White Wares Division.) Received January 15, 1927.

Glazed with:

0.2 PbO 0.2 K_2O 0.1 Na_2O 0.3 CaO 0.2 ZnO	0.3 Al_2O_3	3.0 SiO_2 0.3 B_2O_3	Cone 4–5

Glaze Frit:

0.1 PbO 0.1 Na_2O 0.2 ZnO	0.5 SiO_2 0.3 B_2O_3	

Frit melted in frit furnace, run into water, dried and added to mill batch of glaze. Apply glaze at 26 ounces per pint.

No evidence of crazing after several months, and glaze shows no yellow tint and is not scratched by a steel point.

Body to Stand Heat Shock

Per cent	
1.5	Beryl
1.5	Feldspar (Canadian)
1.5	Calcined magnesium oxide—cone 12
6.5	Al_2O_3
25.0	Calcined kaolin—cone 12
4.0	Flint
15.0	Kentucky ball clay
15.0	Florida kaolin
15.0	Georgia kaolin
15.0	Delaware kaolin

Fired to cone 15—showed 6% absorption

No. 1.—Heat shock test of heating to 1500°F and exposing to blast of cold air from compressed air system. Stood this test 3 times without apparent injury.

No. 2.—Same test but cooled by plunging half the length of trial into running cold water. Stood this test 8 times without apparent injury.

Influence of $CaCO_3$ and $MgCO_3$ on Color of Vitreous China

With china bodies that do not contain more than 15% of ball clay, not more than 50% total clay, and not more than 24% feldspar, the best color is obtained by using $CaCO_3$ and $MgCO_3$ in the proportions 60% $MgCO_3$, 40% $CaCO_3$, and not more than a total of 2.25% of both.

CERAMIC DEPARTMENT
LORD HALL, O. S. U.
COLUMBUS, OHIO

SHEET STEEL COOKING WARE WHITE ENAMELS ECONOMICALLY SUITABLE FOR USE IN CHINA[1]

By Chi-Fang Lai

ABSTRACT

The research was carried on to develop data on sheet steel enamels which would be good enough and cheap enough for use in China. Substitutes for tin oxide were tested.

An efficient and cheaply constructed kerosene fired enameling furnace was designed and built. Little could be gained by work on the ground coats.

Sodium antimonate and calcined alumina yielded the cheapest enamels with quality almost equal to enamels made with tin oxide. Zirconium oxide yielded the best results when tested with acids. Cryolite could be reduced to the minimum and with benefit to the resulting product. High feldspar enamels proved to be most satisfactory. High zinc oxide content greatly increased the gloss but lowered the opacity. Calcined alumina failed when used alone.

Introduction

Every enameler has recognized that the varying of compositions and the use of substitutes for tin oxide in the enameling industry are important and interesting points in the quality and cost of these products. It is true that the enameling industry today has reached a high state of development, but for improvements in the future, probably the ceramist needs to deal with additional raw materials and new methods.

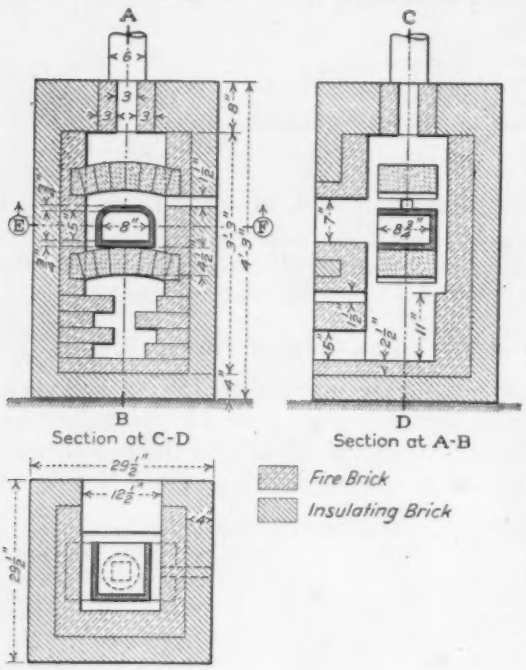

Fig. 1.—Detail drawing of a Carborundum muffle furnace for testing enameled ware.

Cooking ware of high quality, should have good strength, resistance to acids and to thermal shock, an opaque enamel, and for low selling price, the cost of the enamel should be materially reduced. This reduction in cost, however, has consisted mainly in substituting cheap forms of

[1] A thesis submitted to the Graduate Faculty for the degree of Master of Science in Ceramic Engineering. Received October 11, 1926. Presented at the Annual Meeting, American Ceramic Society, Detroit, Mich., Feb., 1927. (Enamel Division.)

chemicals for more expensive forms and the elimination of a few expensive ingredients of little importance.

Plan of Investigation

In this investigation, two typical ground coats and four cover coats were studied. One ground coat is high in feldspar, borax, and cobalt oxide, and the theoretical coefficient of expansion of the enamel is comparatively low; the other is high in quartz and cryolite but low in cobalt oxide, and the theoretical coefficient of expansion of its enamel is higher than the former. In the cover coats, Series A has the refractory portion of the base enamel, high in quartz, low in feldspar, and highest in cryolite; series B has the refractory portion of the base enamel entirely of quartz, but with the cryolite content still high; series C has the refractory portion of base enamel high in feldspar, low in quartz, and with a medium quantity of cryolite; Series D, the other extreme to Series B, has feldspar for the only refractory portion and a total absence of cryolite.

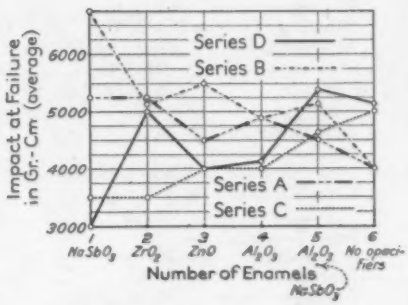

FIG. 2.—Results of impact test.

In each series the various fluxes were almost of the same content, but the opacifiers were substituted systematically one for another in the mill batch for tin oxide.

The theoretical coefficients of expansion of the enamels were calculated from the theoretical melted weight and factors of coefficients of expansion of the frit according to the values assigned to the oxides by Mayer and Havas.[1]

Materials Used

The partial list of factors of theoretical melted weights and coefficients of expansion of raw materials were copied from a paper by Mayer and Havas.[2] The partial list of cost of raw materials was copied from *Ceramic Industry*.[3]

Preparation of Enameling Steel

Stamped six-inch dishes made by the Coonley Manufacturing Company, were used as test samples. These dishes were first scaled in a red-hot furnace and then pickled in an 8% solution by weight of hydrochloric acid for about 15 to 20 minutes. The dishes were taken

[1] M. Mayer and B. Havas, "The Function of Fluorine Compounds in Enamels," *Sprechsaal*, **42**, 460–66; *Chem.-Ztg.*, **33**, 758 (1909).

[2] *Loc. cit.* See also Bur. Stand., *Tech. Paper*, No. 142; *Ceramist*, **4** [1], 12–13 (1924); R. D. Landrum, "Enamels," p. 106; and *Bull. Amer. Ceram. Soc.*, **5** [2], 119 (1926).

[3] *Ceram. Ind.*, **5** [5], 458 (1925).

TABLE I

Raw materials	Formula	Equivalent	Melted weight	Coefficient of expansion	Cost per pound
Feldspar	0.402 Na_2O 0.573 K_2O 0.071 CaO 0.053MgO 1.00 Al_2O_3 7.146 SiO_2	620	1	2.58	$0.0115
Borax	Na_2O, $2B_2O_3$ 10 H_2O	382	0.53	1.66	0.0550
Quartz	SiO_2	60	1.00	0.80	0.0100
Soda ash	Na_2O, CO_2	106	0.58	5.8	0.0240
Sodium nitrate	Na_2O, N_2O_5	170	0.365	3.65	0.0600
Saltpeter	K_2O, N_2O_5	202	0.466	4.76	0.0760
Fluorspar	CaF_2	78	1.000	2.50	0.0190
Whiting	CaO, CO_2	100	0.560	2.80	0.0115
Magnesia	.7885 MgO .0195 CaO	40	1.000	0.10	0.0700
Cryolite	$3Na_2O$, Al_2O_3 $6F_2$	420	"	7.40	0.1000
Zinc oxide	ZnO	81	"	2.10	0.0790
Sodium antimonate	Na_2O, Sb_2O_5	382	"	4.64	0.1800
Cobalt oxide (black)	Co_3O_4	80	0.933	4.100	2.2000
Manganese dioxide	MnO_2	87	0.900	2.000	0.0775
Zirconia	ZrO_2	122.6	1.000	0.800	0.5000
Johnson-Porter clay	Al_2O_3, $2SiO_2$ $2H_2O$	258	0.860	2.440	0.0110

from the acid solution and washed in hot water two or three times, put into a very weak soda solution for about three minutes to neutralize the acid, then taken out and washed again with hot water. Then they were put into a 2% solution of boiling borax for about three minutes. The advantage of using borax solution is that the steel is better prepared for the ground coat and also that the ware can stand a longer time without re-rusting, according to the E. A. Worham practical suggestions. After the borax solution treatment the ware was dried as quickly as possible to prevent re-rusting. Then the sample dishes were ready for enameling.

Preparation of Enamels

Mixing and Smelting The various enamel batches as shown in Tables II and III, were weighed out with five kilograms for each base enamel batch, on a balance sensitive to one hundredth of a gram. They were mixed very thoroughly on a linoleum cloth, screened through a 40-mesh sieve, and then smelted, two hundred grams at a time, in an oil-fired crucible furnace, at temperatures varying from 2000 to 2200°F. This smelting required from 20 to 55 minutes according to the enamel characteristic. The molten frit was then poured into cold water to facilitate subsequent grinding. The resulting frits were poured from the water on screens to allow to dry.

TABLE II

Batch Weight of Ground Coats in Per Cent

Raw Materials	No. I	No. II	No. I	No. II	
Feldspar	32.00	24.00	Saltpeter	2.70	——
Quartz	14.00	26.00	Fluorspar	4.70	——
Borax	38.00	31.20	Cryolite	——	8.00
Soda ash	6.50	6.00	Cobalt oxide	0.70	0.50
Sodium nitrate	——	3.00	Manganese dioxide	1.40	1.30
				100.00	100.00

TABLE III

Batch Weight of Cover Coats in Per Cent

Raw Materials	No. A	No. B	No. C	No. D
Feldspar	18.00	——	36.00	52.00
Quartz	35.00	52.00	19.00	——
Borax	22.00	22.00	20.00	22.00
Soda ash	2.00	4.00	1.00	——
Sodium nitrate	——	——	——	4.00
Saltpeter	1.00	2.50	5.00	——
Calcite	——	3.50	5.00	——
Magnesia	2.00	——	1.00	——
Fluorspar	——	——	1.00	9.00
Cryolite	20.00	16.00	12.00	——
Zinc oxide	——	——	——	4.00
Sodium antimonate	——	——	——	9.00
	100.00	100.00	100.00	100.00

TABLE IV

Theoretical Melted Weights, Coefficients of Expansion and Cost

	Ground coat		Cover coat			
	No. 1	No. 2	No. A	No. B	No. C	No. D
Theoretical melt weight	78.0%	81.0%	88.0%	85.0%	85.0%	87.0%
Theoretical coefficient of expansion	2.89^{-10}	3.28^{-10}	3.12^{-10}	2.83^{-10}	3.23^{-10}	2.96^{-10}
Cost, per hundred pounds of frit (dollars)	6.04	5.43	4.55	4.35	4.12	4.83

Milling The various dried enamel frits were milled with the required opacifier, clay, magnesia, borax and water, about four hundred grams at a time, in a small porcelain ball mill. The amounts of mill batch for the various enamels, are shown in Tables V and VI. The time required for the milling varied from 4 to 8 hours. After the enamel slips were ground to a desirable condition, they were screened, ground coat through an 80-mesh sieve, and cover coat through a 100-mesh sieve. Then the various enamel slips were stored and kept ready for dipping.

Dipping and Drying The dish was dipped in the slip and then set on the special pin board to allow the excess to run off at the bottom. Then the dipped dish was dried in the steam drier as quickly as possible. It is not only the ground coat that should be dried as rapidly as possible to prevent rusting of the steel, but for the cover coats also, rapid drying is desirable, because, especially in the case of white enamels, dirt, in the form of dust sticks to the ware while wet, and therefore rapid drying of the white enamel coats makes for pure white ware. Another point in favor of rapid drying of finished ware is the need of space for storing the ware. After the dipping and drying, the ware can be handled and stored, and is ready for firing.

Firing The dipped and dried dishes were fired in a new oil-fired muffle furnace as shown in Fig. 1.

TABLE V

Mill Batch for Ground and Cover Coats

Materials	Batch for Ground Coat	Batch for Cover Coat
Frits	100.00	100.00
Clay	7.00	6.00
Borax	1.50	———
Magnesia	———	0.50
Opacifiers	———	10.00
Water	50.00	50.00

TABLE VI

Type and Percentage of Opacifiers Used

Opacifiers 10% used	Time for milling in hours series B	B	C	D
Sodium antimonate	5	4	6	8
Zirconium oxide	"	"	"	"
Zinc oxide	"	"	"	"
Calcined alumina	"	"	"	"
Mixture of alumina and sodium antimonate	"	"	"	"
Non-opacifiers	"	"	"	"

To determine the best firing temperature for various enamel coats, small enameled test pieces were first fired, keeping the same temperature but only varying in time, from one minute to six minutes. The one ground coat and two cover coats were fired according to the best results of the preliminary tests and the required times and temperature also noted. After this, the fired dish was stored and ready for testing.

Methods for the Testing of Ware

Resistance of Enameled Ware to Impact The enameled dishes were tested for resistance to impact by the method as used by Danielson and Sweely and Wolfram.

Resistance of Enameled Ware to Thermal Shock

The test employed in this work is the same as used by Landrum[1] and divided into the following five steps of testing:

Test 1.—Twenty-five cc water were added into the dish and heated to boiling on the wire gauze over a Bunsen flame; the dish was then plunged into cold water. The effect of this treatment on the enamel was recorded.

Test 2.—The dish from Test 1 was dried, heated on the wire gauze over the Bunsen flame for one minute, and then plunged into cold water and any results noted.

Test 3.—In the dish from Test 2 a few cubic centimeters of water were boiled away and then the dish was allowed to remain dry over the flame for one minute and was again plunged into cold water. The result was noted.

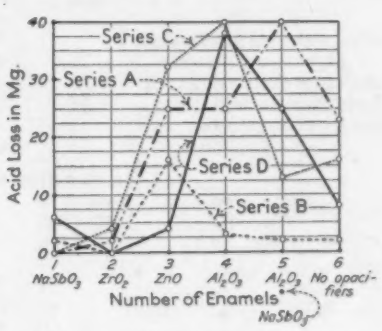

FIG. 3.—Loss in weight of the enameled disk by the acid tests.

Test 4.—The dried dish from Test 3 very gradually heated in the blast flame until the bottom became red-hot. The results of this rapid expansion were noted.

Test 5.—While the dish was still red-hot from Test 4 it was plunged into cold water and the effect of this rapid contraction upon the enamel coating was recorded.

Opacity Opacity was determined by visual estimate. The finished dishes were arranged in a series and carefully examined by two observers. The order of opacity of various enamels was noted.

Resistance of Enameled Ware to Acid Each dish was carefully dried and weighed correctly to 0.0001 gram, and 15 cc of 25% acetic acid were measured into it. It was then placed on the gas-fired hot plate and boiled to dryness, the plate being so regulated that about thirty minutes were required to bring the vessel to dryness. The enameled dish was then washed out thoroughly with distilled water, rinsed, dried on the hot plate, cooled in a desiccator and again weighed. The difference in weight was the amount of enamel dissolved by acetic acid and all conditions were noted.

Results

The physical data of various enamel frits are shown in Table VII. This table also includes the calculated theoretical and actual melted weights and loss on smelting.

[1] *Trans. Amer. Ceram. Soc.*, **13**, 494–501 (1911).

TABLE VII

No. of enamels	Ground coat No. 1	Ground coat No. 2	Cover coat No. A	Cover coat No. B	Cover coat No. C	Cover coat No. D
Time for smelting (minutes)	25	20	20	26	32	55
Temp. for smelting (°F)	2000–2200		2000	2000	2000	2200
Nature of melt	Slightly viscous	Fairly fluid	Fairly fluid	Very fluid	Slightly viscous	Very viscous
Physical properties of frit	Soft darkish blue	Soft light blue	Yellowish white opaque soft	White slightly opaque soft	White opaque soft	Dark very opaque hard
Theoretical melted weight (%)	78	81	88	85	85	87
Actual melted weight (%)	76	75	79	78	74	75
Loss on smelting (%)	24	25	21	22	26	25

TABLE VIII

Data on Firing of Ground Coated Dishes

No. of Samples	Temp. in °F	Time (minutes)	Appearance
No. 1	1650–1700	1½–2.	Satisfactory
No. 2.	1660–1720	1–1½	Satisfactory and good gloss

TABLE IX

Data on Firing of Cover Coated Dishes

No. and Series	On ground No.	Temp. (°F) 1st coat	Temp. (°F) 2nd coat	Time (minutes) 1st coat	Time (minutes) 2nd coat	Appearance of Ware
Series A-1	1	1650	1660	1½	1½	Good gloss and fair white, opaque
1	2	"	"	"	"	Good gloss and fair white opaque
2	1	1700	1700	"	"	Good gloss and fair white opaque
2	2	"	"	"	"	Good gloss and fair white, opaque
3	1	1650	1650	1¼	1¼	Good gloss, medium opaque and light white
3	2	"	"	"	"	Good gloss, poor opaque and white
4	1	1680	1680	1¾	1¾	Matt and pinhole
4	2	"	"	"	"	Matt and poor color
5	1	1670	1680	2	2	Slightly crawled
5	2	"	"	"	"	Fair gloss and white
6	1	1650	1650	1½	1½	" " " "
6	2	1660	1660	"	"	" " " "
Series B-1	1	1650	1650	"	"	Good gloss and light white
1	2	"	"	"	"	Good gloss and fair white
2	1	1680	1680	2	2	Fair gloss and pinhole
2	2	"	"	"	"	Good gloss and fair white
3	1	1650	1650	1½	1½	Fair gloss and white
3	2	1660	1660	"	"	Best gloss, but not very opaque
4	1	1680	1580	2	2	Fair gloss and little matt
4	2	1690	1690	"	"	Fair gloss and slightly matt
5	1	1670	1660	"	"	Fair gloss and not white enough
5	2	"	"	"	"	" " " " "
6	1	1650	1650	1½	1½	Fair gloss and white but pinhole and chipping

TABLE IX (*concluded*)

No. and Series	On ground No.	Temp. (°F) 1st coat	Temp. (°F) 2nd coat	Time (minutes) 1st coat	Time (minutes) 2nd coat	Appearance of Ware
6	2	"	1660	"	"	Fair gloss and white; slight tendency to chipping
C-1	1	"	1650	1¾	1¾	Good gloss and white and fair opacity
1	2	"	"	"	1½	Best gloss, white and opaque
2	1	1680	1680	2¼	2¼	" " " "
2	2	"	"	"	"	" " " "
3	1	1660	1660	1¾	1¾	Best gloss, but not white and opaque enough
3	2	"	"	1⅝	1⅝	Best gloss, but not very white and opaque
4	1	1680	1680	2¼	2¼	Fair gloss, but not white and opaque
4	2	1690	1700	2	2	" " " "
5	1	1670	1670	1¾	1¾	Fair gloss and white
5	2	1680	1680	"	"	Good gloss, white, and opaque
6	1	"	"	1½	1½	Fair gloss and white
6	2	1660	1660	"	"	Fair gloss, white and opaque
D-1	1	1680	1680	1¾	1¾	Best gloss, white and opaque
1	2	"	"	"	"	" " " "
2	1	1700	1700	2	2	" " " "
2	2	"	"	"	"	" " " "
3	1	1680	1680	1¾	1¾	Best gloss, good white and opaque
3	2	"	"	"	"	" " " "
4	1	1700	1700	2¼	2¼	Good gloss, but not white enough and chipping
4	2	"	"	"	"	Good gloss, but not white enough, slightly chipping
5	1	1680	1680	2	2	Good gloss, white and opaque
5		"	"	"	"	Best gloss, white and opaque
6	1	1660	1660	1¾	1¾	Good gloss, white and opaque
6	2	"	"	"	"	Best gloss and opaque but cream white

Tests of physical and chemical properties of the various enamels are recorded in Tables X, XI, XII, XIII, and XIV and in Fig. 2.

TABLE X

Impact Test on Dishes Coated with No. 1. Ground Coat

Cover Enamels Series	1000 gr. cm.	2000 gr. cm.	3000 gr. cm.	4000 gr. cm.	5000 gr. cm.	Failure at center of dish in gr. cm.
A-1			No action	Crazing	Fail	5000
2					Crazing	5000
3			Crazing	Fail		4000
4			"	"		4000
5			"	"		4000
6			"	"		4000
B-1					No action	7000
2			No action	Crazing	Fail	5000
3				"	"	5000
4			Crazing	Fail		4000

TABLE X (*concluded*)

Cover Enamels Series	1000 gr. cm.	2000 gr. cm.	3000 gr. cm.	4000 gr. cm.	5000 gr. cm.	Failure at center of dish in gr. cm.
5				Crazing	Fail	5000
6			Crazing	Fail		4000
C-1	No action	No action	Fail			3000
2		Crazing	"			3000
3			Crazing	"		4000
4		"	Fail			3000
5			Crazing	"		4000
6				Crazing	Fail	5000
D-1		"	Fail			3000
2			No action	Crazing	Fail	5000
3		"	Fail			3000
4		"	"			3000
5					Crazing	5000
6				"	Fail	5000

TABLE XI

Impact Test on Dishes Coated with No. II Ground Coat

Cover Enamels Series	1000 gr. cm.	2000 gr. cm.	3000 gr. cm.	4000 gr. cm.	5000 gr. cm.	Failure at center of dish in gr. cm.
A-1					Crazing	5500
2					No action	"
3				Crazing	Fail	5000
4				No action	Crazing	5750
5					"	5000
6			Crazing	Fail		4000
B-1					No action	6500
2				No action	Crazing	5250
3					"	6000
4					"	5750
5					Crazing	5250
6			Crazing	Fail		4000
C-1	No action	No action	No action	"		4000
2		No action	Crazing	"		"
3			"	"		"
4				Crazing	Fail	5000
5					Crazing	5250
6				"	Fail	5000
D-1	No action	Action	Fail			3000
2				"	"	5000
3				"	"	"
4				No action	Crazing	5250
5					"	5750
6					"	5250

TABLE XII

Thermal Shock Test on Dishes Coated with No. 1 Ground Coat

Cover Enamels Series	Test III	Test IV	Test V	Remarks
A-1	No action	Cracked	Failure	Chipped out
2	" "	No action	Cracked	Cracked only in edge
3	" "	No action	"	" "
4	" "	Cracked	Failure	Chipped out
5	" "	"	"	" "
6	" "	"	"	" "
B-1	" "	"	"	" "
2		No action	Cracked	
3		" "	"	
4		" "	"	
5		" "	"	
6		" "	"	
C-1		" "	"	
2		" "	"	

TABLE XII (*concluded*)

Cover Enamels Series	Test III	Test IV	Test V	Remarks
3		Cracked	Failure	Chipped out
4		" "	"	" "
5		No action	Cracked	
6		" "	"	
D-1		" "	"	
2		" "	"	
3	Cracked	Failure		Very poor
4	"	"		" "
5		"	Failure	
6		Failure		Chipped out

TABLE XIII

Thermal Shock Tests on Dishes Coated with No. 2 Ground Coat

Cover Enamels (Series)	Test IV	Test V	Remarks
A-1	No action	Slightly crazed	Good
2	" "	O.K.	
3	Crazing	Cracked	Chipped slightly
4	No action	O.K.	Good
5	" "	"	Best
6	" "	"	"
B-1	" "	Slightly cracked	
2	" "	O.K.	"
3	" "	Cracked	Fair
4	No action	O.K.	
5	" "	Slightly cracked	
6	" "	Slightly cracked	
C-1	" "	O.K.	Best
2	" "	"	"
3	" "	"	"
4	Cracked	Fail	Fair
5	No action	O.K.	Best
6	" "	Slightly cracked	
D-1	" "	O.K.	Good
2	" "	"	Slightly crazed
3	" "	"	Good
4	Crazed	Cracked	Failure
5	No action	O.K.	Best
6	" "	"	"

TABLE XIV

A Summary of All Physical and Chemical Properties of Various Enamels

No. and Series	Appearance of finished ware	Cost per 100 lbs. of enamel	Impact test average in gr. cm.	Thermal test	Opacity		Acid test loss in mg.
					Observer No. 1	Observer No. 2	
A-1	O.K.	6.00	5250	Good	5th best	A	None
2	"	8.9	5250	O.K.	24th "	C	2
3	"	5.00	4500	Chipped slightly	12th "	B	25
4	Matt	5.2	4875	Good	23rd "	D	25
5	Slightly crazed	5.6	4500	Best	8th "	C	40
6	O.K.	4.75	4000	"	7th "	C	23
B-1	"	5.7	6750	"	16th "	B	2
2	"	8.5	5125	Fair	19th "	C	None

No. and Series	Appearance of finished ware	Cost per 100 lbs. of enamal	Impact test average in gr. cm.	Thermal test	Opacity		Acid test loss in mg.
					Observer No. 1	Observer No. 2	
3	O.K.	5.0	5500	Failure	20th Best	C	16
4	Little matt	5.0	4875	"	29th "	D	3
5	O.K.	5.4	5125	Fair	18th "	C	2
6	"	4.52	4000	"	11th "	C	2
C-1	"	5.5	3500	Best	4th "	A	None
2	"	8.2	3500	"	3rd "	A	4
3	"	4.6	4000	"	13th "	B	32
4	"	4.9	4000	Fair	21st "	C	40
5	"	5.2	4625	Best	17th "	B	13
6	"	4.3	5000	Fair	14th "	C	16
D-1	"	6.10	3000	Good	1st "	A	6
2	"	8.90	5000	Fair	2nd "	A	None
3	"	5.30	4000	Good	10th "	B	4
4	"	5.40	4125	Failure	15th "	C	38
5	"	5.75	5375	Best	9th "	A	25
6	"	5.00	5125	"	6th "	C	8

Summary

The best ground coats were obtained in the cases where there were higher values of theoretical coefficients of expansion than of the cover coats. In the cover coats those of high content of feldspar and low content of fluoride, quartz, and zinc oxide gave best results.

The effects of substitutes for tin oxide on the physical and chemical properties of the cover enamels were pronounced in the cases of sodium antimonate and zirconium oxide; the mixture of sodium antimonate and calcined alumina is also good and cheaper. Although zinc oxide seems to make a very good gloss in enamels it is not satisfactory when used alone for an opacifier.

Costs are also highly important parts in this investigation. The mixture of sodium antimonate and calcined alumina is the cheapest and most desirable opacifier, next the sodium antimonate, then the zirconium oxide. It might be possible that the mixture of zinc oxide and sodium antimonate or zinc oxide and zirconium oxide or sodium antimonate and zirconium oxide would give more satisfactory results economically, but this field may be worked out in the future.

Conclusions

1. The influence of composition of various enamels on physical and chemical properties is more marked in the cover coats than in the ground coats.

2. In the case of the ground coats, except the thermal test, no differences were noted. For greater resistance to thermal shock, the wares were coated with enamels of higher value of theoretical coefficient of expansion in ground coat than the cover coat, and the better result was obtained from the No. 2 ground coat.

3. In the case of cover coats, the increasing of quartz at the expense of feldspar gave slightly decreased impact strengths, opacities, and

resistances to thermal shock, but increase of acid resistance. The increasing of feldspar at the expense of quartz gave slightly decreased acid resistance, but more opacity and resistance to thermal shock. High content of cryolite does not yield opacity proportionate to the expense. So the enamels containing both quartz and feldspar and lower fluoride contents were more satisfactory for general purposes.

4. In the case of substitute opacifiers for tin oxide, sodium antimonate, and zirconium oxide gave best results and are nearly as good as tin oxide itself. They also improved some physical and chemical properties, especially zirconium oxide increased resistance to thermal shock and acid, and sodium antimonate increased impact strength, etc. These advantages seem to be more notable in high feldspar and low quartz and fluoride enamels. Next to these the mixture of sodium antimonate and calcined alumina is good and much cheaper in cost than the zirconia and sodium antimonate. Zinc oxide seems to improve very actively the gloss of enamels but slightly decreases the opacity, and resistance to acid, so that it fails to satisfy the requirements for a good opacifier, but may be classed as fair. Calcined alumina also fails when used alone and makes matt instead of gloss on high fluoride enamels.

5. Considering the cost of various enamels the base enamel, Series C, is cheapest, then the Series B, A, and D. In general, the Series C is desirable in cost and the quality is as good as when tin oxide is used. It may therefore be classed as best from the economical standpoint. The Series D, however, is a more expensive enamel, but the quality is very good in all cases, so it may be classed as next best. The Series A and B, in some cases are also of good quality and their costs are fair, so they may be classed as fair.

6. Use showed that the laboratory furnace designed and built for this work, was entirely satisfactory and a piece of laboratory equipment to be recommended.

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EFFECTS OF COMPOSITION ON THE PROPERTIES OF GROUND COAT ENAMELS FOR SHEET STEEL[1]

By W. N. Harrison and H. G. Wolfram

ABSTRACT

A series of ground coats was developed about each of three refractory bases, one of which consisted of flint and feldspar in a ratio frequently used commercially, another consisting of feldspar only, and the third of flint only. In each case the refractory portion was 58.5 parts of the whole. Besides the refractory, a "fixed addition" of 11.5 parts, comprised of 0.5 cobalt oxide, 1.0 manganese oxide, 5.0 boric oxide and 5.0 sodium oxide, was used in every enamel, bringing the basic constant portion for each series to 70 parts of the whole. The variable portion in each series was made up of equal parts of three constituents commonly used in enameling, chosen from a total of six in such a way that every possible combination was employed, making a total of twenty enamels in each series. All were given two cover coats of a standard white and tested for resistance to mechanical and thermal shock. In general the ingredients which were most conducive to resistance to the test treatments were flint in the refractory portion, and sodium oxide in the variable portion, constituted of fluxes. Also, boric oxide favorably influenced resistance to mechanical shock in the series containing both flint and feldspar. Resistance to mechanical and thermal shock in ground coats was considerably less affected by variations in expansivity than is the case in cover coats, the influence of that factor appearing to be partially obscured by other factors.

Introduction

In a recent issue of this *Journal* there appeared an article describing the results of an investigation by the Bureau of Standards of a large number of white cover enamels of widely different compositions.[2] The present report describes an extension of the investigation to a number of ground coat enamels, which are similar in composition to the cover enamels studied, except that the ground coats contain cobalt and manganese oxides. The purpose of the work was to determine the effects of greater changes in composition than have heretofore been attempted, and to obtain results which might lead to increasing the present number of practical enamels.

Plan of Investigation

The plan of the investigation was to compare three different types of "refractory portions"[3] and also six different fluxes by employing them in various combinations of three.

[1] Published by permission of the Director of the Bureau of Standards, U. S. Department of Commerce. Received January 10, 1926.

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[2] H. G. Wolfram and W. N. Harrison, "Effects of Composition on the Properties of Sheet Steel Enamels," *Jour. Amer. Ceram. Soc.*, **8** [11], 735–55 (1925).

[3] The refractory portion includes feldspar when any feldspar is present in an enamel. Though not considered as a refractory in other branches of the ceramic industry, feldspar is so considered in the enameling industry, since it is much more refractory in enamels than the constituents ordinarily classed as fluxes.

The batch compositions of the enamels are given in Table I. The relation of the variable to the constant portions is illustrated in Chart I. For convenience the constituents are listed under three designations; the "fixed addition," the "refractory portion" and the "variable portion."

TABLE I (Batch Weights)

Parts by Weight

Enamel Designation	Refractory[1]	Borax	Boric acid	Sodium nitrate	Soda ash	Cryolite	Fluorspar	Red lead	Zinc oxide	Cobalt oxide	Manganese dioxide
ABC	58.5	40.9	—	4.8	11.4	10.0	—	—	—	0.5	1.2
ABD	58.5	40.9	—	4.8	11.4	—	10.0	—	—	0.5	1.2
ABE	58.5	40.9	—	4.8	11.4	—	—	10.2	—	0.5	1.2
ABF	58.5	40.9	—	4.8	11.4	—	—	—	10.0	0.5	1.2
ACD	58.5	20.1	13.5	4.8	—	10.0	10.0	—	—	0.5	1.2
ACE	58.5	20.1	13.5	4.8	—	10.0	—	10.2	—	0.5	1.2
ACF	58.5	20.1	13.5	4.8	—	10.0	—	—	10.0	0.5	1.2
ADE	58.5	20.1	13.5	4.8	—	—	10.0	10.2	—	0.5	1.2
ADF	58.5	20.1	13.5	4.8	—	—	10.0	—	10.0	0.5	1.2
AEF	58.5	20.1	13.5	4.8	—	—	—	10.2	10.0	0.5	1.2
BCD	58.5	13.6	—	4.8	18.8	10.0	10.0	—	—	0.5	1.2
BCE	58.5	13.6	—	4.8	18.8	10.0	—	10.2	—	0.5	1.2
BCF	58.5	13.6	—	4.8	18.8	10.0	—	—	10.0	0.5	1.2
BDE	58.5	13.6	—	4.8	18.8	—	10.0	10.2	—	0.5	1.2
BDF	58.5	13.6	—	4.8	18.8	—	10.0	—	10.0	0.5	1.2
BEF	58.5	13.6	—	4.8	18.8	—	—	10.2	10.0	0.5	1.2
CDE	58.5	13.6	—	4.8	1.7	10.0	10.0	10.2	—	0.5	1.2
CDF	58.5	13.6	—	4.8	1.7	10.0	10.0	—	10.0	0.5	1.2
CEF	58.5	13.6	—	4.8	1.7	10.0	—	10.2	10.0	0.5	1.2
DEF	58.5	13.6	—	4.8	1.7	—	10.0	10.2	10.0	0.5	1.2

[1] Series I contains 58.5 parts feldspar, no flint.
" II " 33.5 " feldspar and 25.0 parts flint.
" III " 58.5 " flint, no feldspar.

The "fixed addition" (Chart I) is the only portion which is common to every enamel studied. It contained 1.0 part manganese, computed as MnO, and 0.5 part cobalt oxide to augment the capacity of the enamels to stick to the iron base. Also, since it was considered inadvisable to use less than 5.0 parts each of both boric and sodium oxides, these were included in the fixed addition, bringing its total to 11.5 parts.

This "fixed addition," plus a "refractory portion" of 58.5 parts of feldspar, formed a nucleus of 70 parts, about which the first series of enamels was planned. The second series differed from the first in that the 58.5 parts of refractory portion were made up of 33.5 parts feldspar and 25.0 parts flint. In the third series of enamels the refractory portion consisted of 58.5 parts flint. Thus in all there were

three series of ground coats, each of which had an individual constant portion of 70 parts.

The remaining 30 parts, constituting the variable portion of fluxes for each series, was made up of 10 parts each of three fluxes chosen from a total of six in such a way that every possible combination was used. The six fluxes studied were: (A) B_2O_3, (B) Na_2O, (C) Na_3AlF_6, (D) CaF_2, (E) PbO and (F) ZnO. Since there are 20 combinations of three out of a total of six, there were 20 enamels in each

CHART I

Fixed Addition (11.5 Parts)
0.5 part cobalt oxide, 1.0 part manganese oxide, 5.0 parts boric oxide and 5.0 parts sodium oxide, common to the 60 ground coats studied.

Refractory Portion (58.5 Parts)

Series I	Series II	Series III
58.5 parts feldspar common to the 20 enamels in this series.	33.5 parts feldspar and 25.0 parts flint, common to the 20 enamels in this series.	58.5 parts flint, common to the 20 enamels in this series.
Variable Portion (30 parts) Composed of 10 parts each of 3 fluxes chosen from a total of 6 so that every combination of 3 was used in a total of 20 enamels. The fluxes were B_2O_3, Na_2O, Na_3AlF_6, CaF_2, PbO, and ZnO.	**Variable Portion (30 parts)** 20 different combinations, same as in Series I.	**Variable Portion (30 parts)** 20 different combinations same as in Series I.

series, or 60 for all three series. The systematic scheme for the introduction of the variables is shown in Table II. This table clearly shows, also, the system used to designate the different enamels. An enamel containing fluxes A, B, and C (boric oxide, sodium oxide, and cryolite respectively) in the variable portion is called enamel ABC, and so on. Attention is called to the fact that, besides the 5.0 parts each of sodium and boric oxides in the fixed addition, some of the enamels also contain one or both of these oxides in the variable portion.

Batches of the ground coats weighing approximately 30 pounds each were melted in a rotary furnace, and first applied to small test plates, which were fired at 850°, 900°, and 950°C (1562°, 1652°, and 1742°F). From the results of these preliminary tests an estimate was made as to the range of temperature in which each enamel would mature to best advantage.

The ground coats were then applied to 8-inch steel dinner plates and covered with two coats of a standard white, tested for resistance to thermal shock tests and also by impact tests on the flat part of the

bottoms of the plates and on the curved edges. The results were finally correlated with the enamel compositions.

The composition of the cover coat applied to each dinner plate was as follows:

Frit (batch composition)	%	Frit (computed composition after melting)	%
Feldspar	32.0	Feldspar	39.3
Flint	18.0	SiO_2	22.1
Borax	25.0	B_2O_3	8.1
Soda ash	4.0	Na_2O	8.2
Sodium nitrate	3.0	Na_3AlF_6	14.7
Cryolite	12.0	Sb_2O_5	2.5
Antimony oxide	2.0	CaF_2	4.9
Fluorspar	4.0	Total	99.8
Total	100.0		

Mill Batch	Parts (by weight)
Frit	100.0
Clay	6.0
Tin oxide	7.0
Magnesium carbonate	0.5
Water	50.0

Methods of Test

The methods of test were the same as those used in the preceding work[1] on cover coats, except that no tests for opacity or acid resistance were necessary.

Thermal Shock Resistance to thermal shock was determined by placing a plate containing 25 cc of water directly over the flame on a gas stove of the ordinary star burner type, the height of the flame being held constant by a controlled gas pressure. After boiling to dryness the plate was allowed to remain over the flame for 15 seconds, and then while still over the flame, 25 cc of water at room temperature was poured rapidly into it. This procedure was repeated ten consecutive times unless a chip 0.25 inch or more in diameter resulted sooner. If such a chip occurred on or before the tenth treatment, the piece was given a rating number corresponding to the number of treatments required to produce the chip. It was found upon examining the results of these tests that the plates which withstood ten treatments could be further classified on the basis of minor defects. These plates were given ratings from 11 to 15, the highest indicating the complete absence of defects. Thus the final ratings run from 1 to 15.

Impact Tests The method of making the impact tests is described in an article by Danielson and Sweely.[2] The apparatus is essentially a pendulum with a hammer of a definite mass (6 oz.).

[1] *Loc. cit.*

[2] R. R. Danielson and B. T. Sweely, "The Relations Between Composition and Properties of Enamels for Sheet Steel," *Jour. Amer. Ceram. Soc.*, **6** [10], 1011–29 (1923).

The kinetic energy (in ft.–lbs.) of this hammer at the instant of striking is taken as a measure of the severity of the blow. The kinetic energy of each succeeding blow is increased by equal increments, making the blow progressively more severe, until the test piece fails.

The results are directly comparable only when specimens and apparatus are of the same size, shape, and mass, and with the same increments of kinetic energy of the hammer blows. The plates were tested for resistance to impact at the center of the bottom and at four equidistant points on the curved edges, the outside of the plate being struck by the hammer. In both cases the blow was normal to the surface at the point of impact. Two hundred and forty plates representing the 60 enamels were tested, a chip 0.25 inch in diameter being considered as indicating a failure. The average value of the energies required to produce failure in the respective tests represents the rating of each enamel.

Results

General The results of the tests are shown in Table II. In this table are included also the calculated coefficients of cubical expansion, and the compositions of the frit, showing the systematic scheme for the introduction of the variable constituents. The coefficients of expansion were calculated from the computed composition of the frit by means of the values assigned to the various oxides and compounds by Mayer and Havas.[1] Although these calculated values are recognized to be only approximate, they are quite useful for giving some idea of the relative standing.

The data given in Table II are rearranged in Table III in such a way that comparison of the rating of an enamel in one test with its rating in another is facilitated. Comparison of different enamels in the same test is also accomplished more easily with the rearranged data. In the latter table a rating of 10 indicates the highest standing, and a rating of 1 the lowest, all the results on the 60 enamels being taken into account.

Thus in the impact tests on the curved edges, the lowest rating (0.122 ft.–lbs. at failure) was given to enamel ACE, Series I, and the highest (0.228 ft.–lbs. at failure) to enamel BDE, Series III. The difference between these two ratings was divided into ten equal intervals, and an enamel with a rating falling in the lowest interval was given a new rating of 1, while one falling in the highest interval was given a new rating of 10. Enamel ADE, series I, with a rating of 0.123 ft.–lbs., fell in the first interval and thus received a new rating of 1, and enamel BEF, Series III, with a rating of 0.223 ft.–lbs., fell in the tenth interval and received a new rating of 10.

[1] Mayer and Havas, *Sprechsaal*, **42**, 497; **44**, 188, 207, and 220.

TABLE II

Calculated Compositions Melted, Calculated Cubical Expansivity, and Results of Tests

Enamel Designaton	Composition of variable portions[1]						Series I[2]				Series II[3]				Series III[4]			
	B_2O_3 (Boric oxide) A	Na_2O (Sodium oxide) B	Na_3AlF_6 (Cryolite) C	CaF_2 (Fluorspar) D	PbO (Lead oxide) E	ZnO (Zinc oxide) F	Coefficient of cubical expansion	Quenching test (Relative units)	Impact on edge (ft.-lbs.)	Impact on center (ft.-lbs.)	Coefficient of cubical expansion	Quenching test (Relative units)	Impact on edge (ft.-lbs.)	Impact on center (ft.-lbs.)	Coefficient of cubical expansion	Quenching test (Relative units)	Impact on edge (ft.-lbs.)	Impact on center (ft.-lbs.)
ABC	10	10	10	—	—	—	388[5]	11	.159	.244	340[5]	10	.173	.294	277[5]	14	.170	.350
ABD	10	10	—	10	—	—	339	15	.164	.294	291	15	.161	.332	228	15	.203	.325
ABE	10	10	—	—	10	—	356	10	.184	.306	308	7	.189	.332	245	15	.192	.382
ABF	10	10	—	—	—	10	332	15	.192	.275	284	15	.194	.332	221	14	.167	.413
ACD	10	—	10	10	—	—	313	2	.177	.219	265	12	.186	.344	202	9	.208	.356
ACE	10	—	10	—	10	—	330	—	.122	.200	282	14	.198	.300	219	4	.198	.338
ACF	10	—	10	—	—	10	306	15	.123	.219	258	13	.189	.338	195	15	.170	.282
ADE	10	—	—	10	10	—	281	5	.123	.200	233	13	.197	.325	170	15	.192	.344
ADF	10	—	—	10	—	10	257	10	.141	.250	209	15	.200	.306	146	13	.159	.306
AEF	10	—	—	—	10	10	274	7	.144	.238	226	15	.170	.256	163	14	.172	.344
BCD	—	10	10	10	—	—	412	12	.172	.263	364	15	.180	.363	301	15	.167	.306
BCE	—	10	10	—	10	—	429	15	.156	.269	381	15	.128	.200	318	14	.197	.338
BCF	—	10	10	—	—	10	405	14	.147	.263	357	13	.139	.232	294	15	.180	.350
BDE	—	10	—	10	10	—	380	5	.141	.244	332	11	.192	.325	269	13	.228	.382
BDF	—	10	—	10	—	10	356	15	.148	.225	308	15	.164	.294	245	2	.209	.332
BEF	—	10	—	—	10	10	373	15	.134	.244	325	15	.147	.238	262	7	.223	.338
CDE	—	—	10	10	10	—	354	14	.134	.225	306	12	.133	.269	243	15	.152	.344
CDF	—	—	10	10	—	10	330	10	.134	.206	282	6	.153	.244	219	13	.169	.325
CEF	—	—	10	—	10	10	347	10	.137	.213	299	12	.144	.219	236	10	.156	.319
DEF	—	—	—	10	10	10	298	14	.158	.256	250	12	.131	.194	187	14	.177	.338

[1] Each series has a constant portion of 70%, composed of 58.5% refractory, 5% sodium oxide, 5% boric oxide, 1% manganese oxide and 0.5% cobalt oxide.

[2] Refractory portion Series I, 58.5% feldspar.

[3] Refractory portion Series II, 33.5% feldspar and 25.0% flint.

[4] Refractory portion Series III, 58.5% flint.

[5] Values for expansivity are to be multiplied by 10^{-7}.

It is apparent from Table III that only a moderate per cent of the total number of ground coats studied can be considered as entirely successful, when the melting behavior and general appearance of the ware, as well as resistance to mechanical and thermal shock, are considered. Enamels ABF and DEF, Series III, and BCD, Series II, were in general best, considering appearance, melting behavior, and test results. Enamels ABE and ABD, Series III, though presenting a somewhat less attractive appearance, are as good under test. Enamel CDF, Series III, is slightly less sturdy under test, but presents a very good appearance.

Effects of Ingredients upon Results

In order to facilitate a comparison of the effects of the various ingredients upon the properties of the enamels, the data were rearranged as shown in Table IV. This arrangement is similar to that used in analyzing the results of the work on cover coats, which preceded this investigation. For the sake of clearness the letters designating the various fluxes are given again here. They are: A, boric oxide; B, sodium oxide; C, cryolite; D, fluorspar; E, lead oxide, and F, zinc oxide. Since there are six variables, and only three are used in each enamel, a comparison may be made by selecting groups of enamels having two of the variable constituents in common, and differing from each other only in a single constituent. Thus in Table IV, under the heading "quenching tests" for Series I, at the top of the table there is a comparison of four enamels of the AB type. These four enamels are identical in 90 parts out of 100; 70 parts made up the constant portion common to the whole series, and 20 (comprised of 10 parts of B_2O_3 and 10 of Na_2O) were common to these four enamels. Reference to Table II will show that these are the first of the series, namely enamels ABC, ABD, ABE and ABF. They differ from each other only in that the final ten parts consist of cryolite, fluorspar, lead oxide, and zinc oxide respectively. Returning to the above mentioned location in Table IV, it is seen that in this particular type of enamel fluorspar and zinc oxide were conducive to greater resistance to thermal shock than cryolite and lead oxide. In the EF type of enamel (the group of four having lead oxide and zinc oxide in common), sodium oxide and fluorspar were more conducive to resistance to thermal shock than cryolite or boric oxide. It will be noticed that the rating for each enamel occurs at three places in the table. Enamel ABC for instance, having boric oxide, sodium oxide, and cryolite in the variable portion, received a rating of 11 in the quenching tests. This value appears in the table under constituent C in an AB type of enamel, constituent B in an AC type, and constituent A in a BC type. This triple use of each value is proper because each group of four enamels represents a distinct type, and each enamel of

TABLE III
Series I

No.	Minutes melting	Melting behavior	FIRING Temperature °C	°F	Time Sec.	Appearance after Firing	Appearance with Cover Coat	Coefficient of cubical expansion[1]	RATINGS Impact on edge	Impact on center	Quenching test
ABC	30	Fluid	850	1562	85	Tendency to crystallize	Slightly fishscaled; tendency to flake	388	4	3	7
ABD	50	"	950	1742	50	Short range	"	339	4	5	10
ABE	58	"	950	1742	50	Smooth, fishscaled	"	356	6	6	7
ABF	66	Fluid, but lumps persistent	900	1652	90	Short range	Slightly fishscaled	332	7	4	10
ACD	75	"	900	1652	90	Pitted and fishscaled	Tendency to flake	313	6	2	1
ACE	38	Normal	850	1562	165	Pitted, short range	Crawled, blistered, tendency to flake	330	1	1	—
ACF	42	Viscous	900	1652	90	Pitted and fishscaled	Fair, slightly fishscaled	306	1	2	10
ADE	52	Normal	850	1562	310	Somewhat pitted	Slightly blistered, tendency to flake	281	1	1	3
ADF	49	Fluid	850	1562	310	Tendency to fishscale	Badly fishscaled, tendency to flake	257	2	3	7
AEF	60	Lumps persistent	950	1742	65	Pitted and fishscaled	Crawled, flaked	274	3	3	4
BCD	62	Fluid	900	1652	70	Short range	Slightly fishscaled, slightly blistered	412	5	4	8
BCE	40	Normal	900	1652	70	Pitted, short range	Slightly blistered	429	4	4	10
BCF	35	Fluid	900	1652	105	Badly pitted, short range	"	405	3	4	10
BDE	46	"	900	1652	105	"	"	380	2	3	3
BDF	36	"	950	1742	50	"	Blistered	356	3	2	10
BEF	174	Frothy, viscous, refractory	950	1742	105	Pitted and bubbled	Slightly blistered	373	2	3	10
CDE	35	Normal	950	1742	70	Thickly pitted, short range, fishscaled	Badly blistered	354	2	2	10
CDF	39	"	950	1742	75	Thickly pitted	Slightly blistered	330	2	1	7
CEF	48	"	950	1742	70	Pitted and blistered	Badly blistered	347	2	1	7
DEF	60	Somewhat viscous	950	1742	80	Pitted and fishscaled	Slightly blistered	298	4	3	10

[1] Values are to be multiplied by 10^{-7}.

TABLE III (*continued*)
Series II

No.	Minutes melting	Melting behavior	FIRING Temperature °C	°F	Time Sec.	Appearance after Firing	Appearance with Cover Coat	Coefficient of cubical expansion[1]	RATINGS Impact on edge	Impact on center	Quenching test
ABC	38	Normal	850	1562	150	O.K.	O.K.	340	5	5	7
ABD	52	"	900	1652	75	O.K.	Some tendency to fishscale	291	4	7	10
ABE	43	Bubbles persistent	900	1652	120	Fishscaled	Fishscaled	308	7	7	4
ABF	45	Normal	900	1652	150	Spots, fishscaled	Slightly fishscaled	284	7	7	10
ACD	60	Lumps persistent	950	1742	95	Fishscaled	Tendency to fishscale	265	7	7	8
ACE	41	"	850	1562	250	Pitted, fishscaled	"	282	8	5	10
ACF	35	Normal	900	1652	135	"	Fishscaled	258	7	7	9
ADE	40	"	875	1607	240	Fishscaled, chipped off at edges	O.K.	233	8	6	9
ADF	45	"	850	1562	280	Pitted, fishscaled	Tendency to fishscale	209	8	6	10
AEF	45	"	900	1652	105	Fishscaled, flaked off at edges	O.K.	226	5	3	10
BCD	35	"	850	1562	130	O.K.	O.K.	364	6	8	10
BCE	30	"	900	1652	90	Rough, bubbled	Badly blistered	381	1	1	10
BCF	40	"	950	1742	50	Badly bubbled	O.K.	357	2	2	9
BDE	25	"	950	1742	50	Fair	"	332	7	6	7
BDF	35	Normal, fluid	950	1742	50	Slightly fishscaled	"	308	4	5	10
BEF	43	Very frothy	950	1742	95	Badly pitted	"	325	3	3	10
CDE	33	Normal	950	1742	105	Rough, bubbled	Fair	306	2	4	8
CDF	77	Lumps persistent	950	1742	75	Pitted, fishscaled	Tendency to crawl, tendency to flake	282	3	3	4
CEF	29	Normal	950	1742	70	Rough, bubbled	A few blisters	299	3	2	8
DEF	31	"	950	1742	80	Pitted, fair	Fair, a few blisters	250	1	1	8

Values are to be multiplied by 10^{-7}.

TABLE III (*concluded*)
Series III

No.	Minutes melting	Melting behavior	FIRING Temperature °C	°F	Time Sec.	Appearance after Firing	Appearance with Cover Coat	Coefficient of cubical expansion[1]	RATINGS Impact on edge	Impact on center	Quenching test
ABC	35	Normal	850	1562	75	Slightly fishscaled	Slightly fishscaled	277	5	8	10
ABD	35	"	925	1697	60	Fair	Fair	228	8	6	10
ABE	35	"	925	1697	90	"	"	245	7	9	10
ABF	45	"	950	1742	90	O.K.	O.K.	221	5	10	10
ACD	45	"	900	1652	180	Slightly fishscaled	Fishscaled	202	9	8	6
ACE	60	"	850	1562	180	Fishscaled	"	219	8	7	2
ACF	60	"	900	1652	90	"	"	195	5	5	10
ADE	80	Slightly viscous	850	1562	180	Very poor	Very poor	170	7	7	10
ADF	85	"	850	1562	150	Slight blisters, poor	Slightly blistered, flaked	146	4	6	9
AEF	75	"	950	1742	95	Very poor	Blistered, fishscaled, very poor	163	5	7	10
BCD	45	Normal	900	1652	100	Slightly fishscaled	Slightly blistered and fishscaled	301	5	6	10
BCE	35	"	900	1652	120	" blistered	"	318	8	7	10
BCF	45	"	950	1742	75	" "	"	294	6	8	10
BDE	40	"	950	1742	120	" fishscaled	Slightly fishscaled	269	10	9	9
BDF	55	"	950	1742	135	" blistered	" blistered	245	9	7	1
BEF	50	"	950	1742	150	" fishscaled	Blistered, fishscaled	262	10	7	4
CDE	50	"	950	1742	135	" blistered	Slightly blistered	243	3	7	10
CDF	55	"	950	1742	90	O.K.	O.K.	219	5	6	9
CEF	55	Slightly viscous	950	1742	100	Badly blistered	Badly blistered	236	4	6	7
DEF	85	"	950	1742	110	O.K.	O.K.	187	6	7	10

Values are to be multiplied by 10^{-7}.

that type if entitled to consideration regardless of the fact that it also falls in another type of group.

By means of the averages of the tabulated values, the constituents can be rated according to their general behavior in the various types of enamels. Thus sodium oxide, with an average value of 14 in the quenching tests of Series I enamels, is rated considerably higher than boric oxide, with an average rating of 10. Yet in one type of enamel (the CF type, having cryolite and fluorspar in the variable portion) boric oxide received the highest rating. There are enough such exceptions to show that though one constituent may rate better than another on the average, the same relationship may not exist in a particular type of enamel. Nevertheless, certain of the constituents studied persistently stood out above others in the various types of compositions. In analyzing the data as shown in Table IV, perhaps the most striking relationship is the marked improvement in resistance to mechanical shock which accompanies the replacement of feldspar by silica. This fact is brought out more clearly by a separate tabulation of the average ratings, shown in Table V. Referring to this table, and considering first the thermal test, it is seen that the Series II enamels average higher than those of Series I and Series III. It is in the mechanical impact tests, however, that the improvement, with inincrease of flint, continues to a marked degree through all three series. Not only is there an average improvement from Series I to Series III, but the rating for each separate ingredient shows a considerable gain for each replacement of feldspar by silica, excepting a single instance in which the ratings are almost equal. The improvement in resistance to impact from Series II to Series III is more than enough to counterbalance the slight impairment in resistance to thermal shock, so that Series III gives distinctly the best average rating.

Another striking relationship brought out by a study of Table IV is the excellent average rating of sodium oxide, throughout all the tests and all three series of enamels. Out of the nine groups of constituents in Table IV, arranged in order of preference under each type of test, for each series, sodium oxide takes six first places, one second, and two third places. Thus of the six constituents compared, sodium oxide is on the whole outstandingly superior, but some of the other ingredients have an exceptionally favorable influence in certain types of enamel. For instance, B_2O_3 has the best average rating in Series II, which includes both feldspar and silica in the refractory portion. The influence of any ingredient, of which the effect varies with the type of enamel, can best be determined, however, by reference to Table IV without further condensation.

TABLE IV
Series I

TEST RATINGS

Type	Variables common to type enamel	Quenching Tests (relative units) A Boric oxide (B_2O_3)	B Sodium oxide (Na_2O)	C Cryolite (Na_3AlF_6)	D Fluor-spar (CaF_2)	E Lead oxide (PbO)	F Zinc oxide (ZnO)	Impact Edge (ft.-lbs.$\cdot 10^{-3}$) B_2O_3	Na_2O	Na_3AlF_6	CaF_2	PbO	ZnO	Impact Center (ft.-lbs.$\cdot 10^{-3}$) B_2O_3	Na_2O	Na_3AlF_6	CaF_2	PbO	ZnO
AB	$B_2O_3-Na_2O$	—	—	11	15	10	15	—	—	159	164	184	192	—	—	244	294	306	275
AC	$B_2O_3-Na_3AlF_6$	—	11	—	2	*—	15	—	159	—	177	122	123	—	244	—	219	200	219
AD	$B_2O_3-CaF_2$	—	15	2	—	5	10	—	164	177	—	123	141	—	294	219	—	200	250
AE	B_2O_3-PbO	—	10	*—	5	—	7	—	184	122	123	—	144	—	306	200	200	—	238
AF	B_2O_3-ZnO	—	15	15	10	7	—	—	192	123	141	144	—	—	275	219	250	238	—
BC	$Na_2O-Na_3AlF_6$	11	—	—	12	15	14	159	—	—	172	156	147	244	—	—	263	269	263
BD	Na_2O-CaF_2	15	—	12	—	5	15	164	—	172	—	141	148	294	—	263	—	244	225
BE	Na_2O-PbO	10	—	15	13	—	15	184	—	156	141	—	134	306	—	269	244	—	244
BF	Na_2O-ZnO	15	—	14	15	15	—	192	—	147	148	134	—	275	—	263	225	244	—
CD	$Na_3AlF_6-CaF_2$	2	12	—	—	14	10	177	172	—	—	134	134	219	263	—	—	225	206
CE	Na_3AlF_6-PbO	*—	15	—	14	—	10	122	156	—	134	—	137	200	269	—	225	—	213
CF	Na_3AlF_6-ZnO	15	14	—	10	10	—	123	147	—	134	137	—	219	263	—	206	213	—
DE	CaF_2-PbO	5	13	14	—	—	14	123	141	134	—	—	158	200	244	225	—	—	256
DF	CaF_2-ZnO	10	15	10	—	14	—	141	148	134	—	158	—	250	225	206	—	256	—
EF	$PbO-ZnO$	7	15	10	14	—	—	144	134	137	158	—	—	238	244	213	256	—	—
Average		10	14	11	11	11	13	153	160	146	149	143	146	245	263	232	238	240	239

Quenching Tests
Average for series, 10.5
Rating
1—Sodium oxide
2—Zinc oxide
3—Cryolite
3—Fluorspar
3—Lead oxide
6—Boric oxide

Impact Edge
Average for series, 149.5
Rating
1—Sodium oxide
2—Boric oxide
3—Fluorspar
4—Cryolite
4—Zinc oxide
6—Lead oxide

Impact Center
Average for series, 242.6
Rating
1—Sodium oxide
2—Boric oxide
3—Lead oxide
4—Zinc oxide
5—Fluorspar
6—Cryolite

* No test made

TABLE IV (*continued*)
Series II

Type	Variables common to type enamel	TEST RATINGS: Quenching Tests (relative units) A Boric oxide (B_2O_3)	B Sodium oxide (Na_2O)	C Cryolite (Na_3AlF_6)	D Fluor-spar (CaF_2)	E Lead oxide (PbO)	F Zinc oxide (ZnO)	Impact Edge (ft.-lbs. 10^{-3}): B_2O_3	Na_2O	Na_3AlF_6	CaF_2	PbO	ZnO	Impact Center (ft.-lbs. 10^{-3}): B_2O_3	Na_2O	Na_3AlF_6	CaF_2	PbO	ZnO
AB	$B_2O_3-Na_2O$	—	—	10	15	7	15	—	—	173	161	189	194	—	—	294	332	332	332
AC	$B_2O_3-Na_3AlF_6$	—	10	—	12	14	13	—	173	—	186	198	189	—	294	—	344	300	338
AD	$B_2O_3-CaF_2$	—	15	12	—	13	15	—	161	186	—	197	200	—	332	344	—	325	306
AE	B_2O_3-PbO	—	7	14	13	—	15	—	189	198	197	—	170	—	332	300	325	—	256
AF	B_2O_3-ZnO	—	15	13	15	15	—	—	194	189	200	170	—	—	332	338	306	256	—
BC	$Na_2O-Na_3AlF_6$	10	—	—	15	15	13	173	—	—	180	128	139	294	—	—	363	200	232
BD	Na_2O-CaF_2	15	—	15	—	11	15	161	—	180	—	192	164	332	—	363	—	325	294
BE	Na_2O-PbO	7	—	15	11	—	15	189	—	128	192	—	147	332	—	200	325	—	238
BF	Na_2O-ZnO	15	—	13	15	15	—	194	—	139	164	147	—	332	—	232	294	238	—
CD	$Na_3AlF_6-CaF_2$	12	15	—	—	12	6	186	180	—	—	133	153	344	363	—	—	269	244
CE	Na_3AlF_6-PbO	14	15	—	12	—	12	198	128	—	133	—	144	300	200	—	269	—	219
CF	Na_3AlF_6-ZnO	13	13	—	6	12	—	189	139	—	153	144	—	338	232	—	244	219	—
DE	CaF_2-PbO	13	11	12	—	—	12	197	192	133	—	—	131	325	325	269	—	—	194
DF	CaF_2-ZnO	15	15	6	—	12	—	200	164	153	—	131	—	306	294	244	—	194	—
EF	$PbO-ZnO$	15	15	12	12	—	—	170	147	144	131	—	—	256	238	219	194	—	—
Average		13	13	12	13	13	13	186	167	162	170	163	163	316	294	280	300	266	265

Quenching Tests
Average for series, 12.7
1—Sodium oxide
1—Zinc oxide
1—Boric oxide
1—Fluorspar
1—Lead oxide
6—Cryolite

Impact Edge
Average for series, 168.4
1—Boric oxide
2—Fluorspar
3—Sodium oxide
4—Zinc oxide
4—Lead oxide
6—Cryolite

Impact Center
Average for series, 286.8
1—Boric oxide
2—Fluorspar
3—Sodium oxide
4—Cryolite
5—Lead oxide
6—Zinc oxide

TABLE IV (*concluded*)

Series III

TEST RATINGS

Type	Variables common to type enamel	Quenching Tests (relative units)						Impact Edge (ft.-lbs. 10^{-2})						Impact Center (ft.-lbs. 10^{-2})					
		A Boric oxide (B_2O_3)	B Sodium oxide (Na_2O)	C Cryolite (Na_3AlF_6)	D Fluor-spar (CaF_2)	E Lead oxide (PbO)	F Zinc oxide (ZnO)	B_2O_3	Na_2O	Na_3AlF_6	CaF_2	PbO	ZnO	B_2O_3	Na_2O	Na_3AlF_6	CaF_2	PbO	ZnO
AB	$B_2O_3-Na_2O$	—	—	14	15	15	14	—	—	170	203	192	167	—	—	350	325	382	413
AC	$B_2O_3-Na_3AlF_6$	—	14	—	9	4	15	—	170	—	208	198	170	—	350	—	356	338	282
AD	$B_2O_3-CaF_2$	—	15	9	—	15	13	—	203	208	—	192	159	—	325	356	—	344	306
AE	B_2O_3-PbO	—	15	4	15	—	14	—	192	198	192	—	172	—	382	338	344	—	344
AF	B_2O_3-ZnO	—	14	15	13	14	—	—	167	170	159	172	—	—	413	282	306	344	—
BC	$Na_2O-Na_3AlF_6$	14	—	—	15	14	15	170	—	—	167	197	180	350	—	—	306	338	350
BD	Na_2O-CaF_2	15	—	15	—	13	2	203	—	167	—	228	209	325	—	306	—	382	332
BE	Na_2O-PbO	15	—	14	13	—	7	192	—	197	228	—	223	382	—	338	382	—	338
BF	Na_2O-ZnO	14	—	15	2	7	—	167	—	180	209	223	—	413	—	350	332	338	—
CD	$Na_3AlF_6-CaF_2$	9	15	—	—	15	13	208	167	—	—	152	169	356	306	—	—	344	325
CE	Na_3AlF_6-PbO	4	14	—	15	—	10	198	197	—	152	—	156	338	338	—	344	—	319
CF	Na_3AlF_6-ZnO	15	15	—	13	10	—	170	180	—	169	156	—	282	350	—	325	319	—
DE	CaF_2-PbO	15	13	15	—	—	14	192	228	152	—	—	177	344	382	344	—	—	338
DF	CaF_2-ZnO	13	2	13	—	14	—	159	209	169	—	177	—	306	332	325	—	338	—
EF	$PbO-ZnO$	14	7	10	14	—	—	172	223	156	177	—	—	344	338	319	338	—	—
Average		13	12	12	12	12	12	183	194	177	186	189	178	344	352	331	336	347	335

Quenching Tests
Average for series, 12.3
1—Boric oxide
2—Sodium oxide
2—Fluorspar
2—Cryolite
2—Lead oxide
2—Zinc oxide

Impact Edge
Average for series, 184.5
1—Sodium oxide
2—Lead oxide
3—Fluorspar
4—Boric oxide
5—Zinc oxide
6—Cryolite

Impact Center
Average for series, 340.6
1—Sodium oxide
2—Lead oxide
3—Boric oxide
4—Fluorspar
5—Zinc oxide
6—Cryolite

In Table VI are shown the ratings of each ingredient, obtained by averaging the results for all three series of enamels. Comparison of these ratings shows again, as in Table IV, the general improvement accompanying a high sodium oxide content, and also shows an excellent agreement in the order of relative merit of the constituents in their ability to resist mechanical shock. Sodium oxide and boric oxide may be considered as about equally good in this respect, followed in order by fluorspar, lead oxide, zinc oxide and cryolite.

Effect of Expansivity

It might seem logical, in view of data already in the literature, to assume that expansivity has a considerable influence upon the behavior of ground coats as well as in the case of cover coats in their resistance to mechanical and thermal shock. On the other hand insofar as ground coats are concerned, other properties which probably include adhesion to the metal base, strength, and elasticity, may be more powerful in their effect than the expansivity.[1] If the influence of the expansivity were as great in ground coats as in cover coats, for which it has been shown that high expansivity is conducive to more resistance for an impact-on-edge and low expansivity to more for one on center,[2] it follows then that the ratings shown in Table VI for the various ingredients should, since the expansivity factors are widely divergent, be different in the different impact tests. Since there is no marked indication of this, it appears that the effect of the expansivity is relatively small. A further indication of the relatively small influence of expansivity upon the resistance of ground coats to mechanical and thermal shock is the fact that the same material (sodium oxide) is conducive to resistance to both the thermal test and the impact on edge. This relation could not exist if expansivity were a controlling factor since high expansivity improves the one resistive quality and impairs the other.[2]

Investigating the same question from another angle, it will be noticed from Table VI that the two ingredients which produce greatest resistance to mechanical impact, namely sodium oxide and boric oxide, have the two extremes of the expansivity factors. Furthermore sodium oxide and silica, which are the two ingredients leading most conspicuously to high test ratings, also represent almost the two extremes of the expansivity factors.

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[1] This statement, of course, refers only to the resistance of the ground coats to mechanical and thermal shock, and not to fishscaling, which has been thoroughly discussed in a previous publication from this Bureau by R. R. Danielson and W. H. Souder, "Causes and Control of Fishscaling of Enamels for Sheet Iron and Steel," *Jour. Amer. Ceram. Soc.*, **4** [8], 620 (1921).

[2] H. G. Wolfram and W. N. Harrison, *ibid.*

TABLE V

Average Rating for Ingredient

Series	Refractory	(A) B_2O_3	(B) Na_2O	(C) Na_3AlF_6	(D) CaF_2	(E) PbO	(F) ZnO	Test	Units
I	Feldspar	10	14	11	11	11	13	Quenching	Relative
II	Feldspar and flint	13	13	12	13	13	13	"	"
III	Flint	13	12	12	12	12	12	"	"
I	Feldspar	153	160	146	149	143	146	Impact on edge	Ft.-lbs.$^{10^{-3}}$
II	Feldspar and flint	186	187	162	170	163	163	"	"
III	Flint	183	194	177	186	189	178	"	"
I	Feldspar	245	263	232	238	240	239	Impact on center	Ft.-lbs.$^{10^{-3}}$
II	Feldspar and flint	316	294	280	300	266	265	"	"
III	Flint	344	352	331	336	347	335	"	"

TABLE VI

Ratings for All Three Series Averaged Together

Quenching Test Ingredient	Rating (rel. units)	Impact on Edge Ingredient	Rating (ft.-lbs $^{10^{-3}}$)	Impact on Center Ingredient	Rating (ft.-lbs.$^{10^{-3}}$)
Sodium oxide	13	Boric oxide	174	Sodium oxide	303
Zinc oxide	12	Sodium oxide	173	Boric oxide	301
Fluorspar	12	Fluorspar	168	Fluorspar	291
Cryolite	12	Lead oxide	165	Lead oxide	284
Boric oxide	12	Zinc oxide	162	Zinc oxide	280
Lead oxide	12	Cryolite	162	Cryolite	276

Conclusions

As the information given in Table II shows, a large majority of the enamels made and tested in the investigation reported here did not "fire" satisfactorily under laboratory conditions. Whether or not they would act similarly under plant conditions, and whether or not the unsatisfactory ones could be improved by a careful study and modification of the melting, milling and firing processes, is not known. In this connection it should be borne in mind that the original purpose of the investigation was to make up and test ground coat enamels varying considerably in composition from those now used commercially irrespective of whether or not the enamels so made were satisfactory in appearance. In other words the investigation was a study of enamels and not of enameling. Furthermore, the results obtained do appear to indicate the manner in which the various oxides used affect the properties of the finished enamel and to that extent they form a basis upon which the manufacturer can modify commercial enamels to develop certain desired characteristics.

Since it is believed that the results are suggestive of the manner in which commercial compositions can be altered to produce desired

results, the general relationships shown by an analysis of the data are recorded here and are as follows:

1. A high feldspar content in ground coats, produced by replacing the customary flint content with feldspar, greatly decreased resistance to mechanical and thermal shock.

2. A high flint content in ground coats, produced by replacing the usual feldspar content with flint, slightly impaired the resistance to thermal shock, but greatly improved resistance to mechanical shock. Ground coats with a high flint content, therefore, in general received the best ratings.

3. Of the six variable constituents studied, namely B_2O_3, Na_2O, Na_3AlF_6, CaF_2, PbO, and ZnO, a high sodium oxide content in ground coats was outstandingly conducive to a high resistance to both mechanical and thermal shock.

4. A high boric oxide content increased resistance to mechanical shock in the series of ground coats containing both feldspar and silica.

5. The effect of expansivity on the resistance of ground coats to mechanical and thermal shock appeared to be obscured by other factors.

VARIATIONS IN SOFTENING POINTS OF REFRACTORY MATERIALS DUE TO RATE OF HEATING[1]

By Sandford S. Cole[2]

ABSTRACT

Results are given of a series of softening point tests upon several types of refractory materials in which the rate of heating to obtain cone 28 down was varied from one hour to five hours. The results are presented in order to show that much of the data obtained by a fusion furnace is dependent upon the rate at which the furnace is heated and that large variations will occur unless care is taken to duplicate conditions of previous tests. Conclusions reached were: that two laboratories must duplicate the essential conditions in order to obtain agreement that the furnaces should be of the same type and heated in a similar manner, that the variations reported by different investigators can often be traced to the fact that conditions have not been duplicated.

Introduction

A study of the available literature has failed to give any pertinent information as to the effect of rate of heating upon the softening point of refractory materials. The standard method, which has been set forth by the American Society for Testing Materials, is well known and it is the method which testing and research laboratories are expected to use in obtaining the softening point of various refractory materials. The use of certain types of fusion furnaces, *i.e.*, electric resistance and oxyacetylene, for obtaining the softening point has increased in the past few years. In such furnaces it is often impractical and impossible to maintain the rate as specified by A.S.T.M. Standards[3]. In order to obtain definite information as to the variation caused in the softening points by varying the rate of heating, a series of tests was made with this object in view. The results which were obtained in this investigation will doubtless be of interest to manufacturers and consumers who are testing refractories.

Description of Tests

Tests were made in a gas-fired furnace 8 inches inside diameter and 10 inches inside height. The materials examined were New Jersey and Pennsylvania siliceous fire clays, Illinois and Missouri plastic fire clays, silica cements, silica brick, flint fire brick and grog fire brick. These materials were selected to include the softening point range usually encountered in testing refractories. The softening points varied from cone 28 to cones 31–32 when the materials were tested in routine work

[1] Presented at the Annual Meeting, American Ceramic Society, Detroit, Mich., Feb., 1927, (Refractories Division). Received Jan. 10, 1927.

[2] The Koppers Company Laboratories, Mellon Institute, Pittsburgh, Pa.

[3] A.S.T.M. Standards, C 24–20, p. 745 (1926).

according to the standard method. The materials were made into test cones by the usual method, *i.e.*, by crushing the brick and fire clay to pass a 65-mesh Tyler Standard Screen and using the silica cement as received.

The test cones were mounted in a plaque made of alundum and plastic clay. In mounting the cones, care was taken to place all cones at the same angle and all plaques were made similar in size and shape. The plaques were placed in the testing furnace in the same position each time in order to eliminate any possible variation due to local furnace conditions.

The furnace was heated with natural gas and the atmosphere was kept oxidizing throughout the test. The furnace was heated at various definite rates until cone 28 was down after which the standard rate of heating was employed. The length of time to reach cone 28 was varied from one hour to five hours. The following table gives the temperature attained at the end of each time period.

TABLE I

No.	30 Min.	1 hr.	1½ hr.	2 hr.	2½ hr.	3 hr.	4 hr.	5 hr.
1	1200°C	28 down						
2	1000°C	1350°C	28 down					
3	900°C	1200°C	1400°C	28 down				
4	800°C	1000°C	1250°C	1400°C	28 down			
5	700°C	800°C	1000°C	1200°C	1400°C	28 down		
6	700°C	800°C	1000°C	1200°C	1300°C	1400°C	28 down	
7	600°C	750°C	900°C	1100°C	1200°C	1300°C	1400°C	28 down

The two and one-half hour rate is similar to the rate set forth in C 24–20 A.S.T.M. standard method for determining the softening point of refractory materials. The results which were obtained with this rate closely checked the softening points obtained in routine work. The hour rate is slower than the rate often used with oxyacetylene furnaces, since it is common to obtain the softening point of a material in less than an hour in such a furnace.

Results Obtained

On account of the number of softening points determined, it is considered advisable to present only a portion of the results obtained, since the entire mass of data might produce a rather cumbersome piece of information. The results selected are representative of all the data. Table II gives the information obtained by the test.

Observations

At first observation the above results seem too widely divergent to be of value, but on analysis it may be seen that this investigation has brought out two facts; first, that certain types of refractory materials

TABLE II

No.	Fire Clay	1 hr.	1½ hr.	2 hr.	2½ hr.	3 hr.	4 hr.	5 hr.
	Fire Brick							
1	Pennsylvania siliceous	29	30–31	30–31	30	30–31	30–31	30–31
2	New Jersey siliceous	29–30	29–30	28–29	29	27–28	29–30	28–29
3	Illinois plastic	30	30–31	30	30–31	29–30	30–31	30–31
4	Missouri plastic	29–30	29–30	30–31	29–30	28–29	30–31	29–30
5	Pennsylvania hand made	32	32	32	32	31–32	31–32	31–32
6	Illinois stiff mud	30–31	31	30–31	30	30–31	30–31	30–31
7	Missouri steam pressed	31–32	31–32	31	30	31	30–31	30–31
	Silica Brick							
8	Mt. Union district	31	31–32	31–32	30–31	30–31	31	31
9	" " "	30–31	31	30–31	30	30–31	30–31	30–31
10	" " "	31–32	31–32	31	30	30–31	30–31	30–31
11	Baraboo "	31	31–32	31–32	30–31	31–32	31	31
12	" "	31	30–31	30	30–31	31	30–31	30–31
	Silica Cement							
13		30	31–32	31–32	31–32	30–31	29–30	30–31
14		28–29	29	29–30	29–30	30–31	29–30	29–30
15		31–32	31	31–32	31–32	31–32	30–31	30–31
16		29	28–29	30–31	29–30	30–31	29–30	28–29
17		28	29	29–30	29	30–31	28	29
18		30–31	28–29	30–31	29–30	30–31	28–29	28–29
19		28–29	27	27–28	27–28	27–28	28–29	28–29
20		27	26–27	27–28	27–28	20–26	20–26	20–26

vary considerably in softening point when the rate of heating is varied, and second, that certain rates will give higher results than other rates. Considering each type of material separately, several conclusions can be drawn.

The fire clays on long heating have not been lowered appreciably in softening point. The New Jersey siliceous and Missouri plastic fire clays are quite erratic, showing two cones variation in softening point. The Pennsylvania siliceous and Illinois plastic fire clays were very regular, the maximum variation of one and one-half cones occurring in only one instance.

The fire brick tended to be more regular than the clays, showing in the case of the Pennsylvania hand-made and Illinois re-pressed, less than one-half cone total variation. The Missouri brick showed one and one-half cones variation, but this occurred only once. As the time of heating was increased, the softening point of the fire brick decreased.

Varying the rate of heating caused a lowering in softening point of the silica brick from one-half cone to one and one-half cones. The longer the cones were heated, the lower was the softening point. The one and one-half hour rate tended to give the highest result in general. The material from the Baraboo district seemed to show less variation.

The silica cements were quite erratic in general, having a variation in every case of at least one cone and usually of two or two and one-half cones. In no case did the variation go over two and one-half cones. The reason for these large discrepancies is rather difficult to account for,

but it may be explained by the fact that the cements were made up of a mixture of granular silica and powdered clay. The chemical reaction which occurs between clay and silica would depend chiefly upon temperature, if the constituents were finely divided and intimately mixed. However, in the present investigation of cements containing coarse silica the time element might be expected to have some effect. Considering the cements separately with respect to their screen analyses, which are given in Table III, there are several facts which present themselves. It should be noted that all of the cements were composed of raw materials from the same sources.

TABLE III

SCREEN ANALYSIS OF SILICA CEMENTS

Number	13	14	15	16	17	18	19	20
On 20-mesh	—	—	—	—	—	—	—	—
On 48-mesh	30.0	20.5	27.8	24.5	6.4	16.6	19.3	22.0
On 100-mesh	28.0	27.0	25.3	25.6	25.4	33.3	25.3	18.1
On 200-mesh	10.7	11.9	10.6	12.1	17.0	9.3	11.9	12.1
Through 200-mesh	31.3	40.6	36.3	37.8	51.2	40.8	43.5	47.8

Cement No. 13, the coarsest cement tested, has in general only one cone variation, although in the four hour heating it was lowered two cones. As the time of heating was increased the softening point was lowered.

Cement No. 14 was a normal cement and the variation was not very great, except in the one hour test in which it was much lower. Cement No. 15 was another typical cement judged from its screen analysis and as the time was increased a lower result was obtained.

Cement No. 16 was very erratic, being neither consistent nor in accordance with the other results. This presents, in a very forceful manner, the effect that the rate of heating may have upon the softening point. Cement No. 17 was the finest ground cement tested, having a low softening point at both rapid and slow heating rates. At the normal rate this cement gave a higher result. Cement No. 18 was a medium fine cement and as the rate of heating was increased the softening point decreased.

Cements No. 19 and No. 20 were low fusion cements which did not behave alike in the changes in softening point. The reason for this may be the variation in screen analysis, which would no doubt have some effect.

Rapid heating, *i.e.*, heating the furnace to cone 28 down in one hour, caused, in general, a lower softening point for silica cements and a higher result for silica brick. The four hour rate tended to give a lower result for the silica cements, in general, and the three hour rate the highest result.

Conclusions

From the results obtained in this investigation the following conclusions have been drawn as to the effect of varying the rate of heating in determining the softening point of various refractory materials.

1. Variations in the rate of heating will cause appreciable differences in the results.
2. Certain materials will vary more than others.
3. Materials which are finely ground and intimately mixed will show less variation.
4. Siliceous fire clays are apt to show considerable variation due to their chemical composition.
5. The purer the material the less the softening point will vary.
6. The results of this investigation forcefully establish the fact that a standard method for determining the softening point of refractories must be used if various testing laboratories are to get comparable results.

KILN CONSTRUCTION[1]

An Efficient Round, Downdraft Kiln for Firing Refractories

By J. B. Lyon

ABSTRACT

Seventeen periodic kilns were studied for construction and design details, operation, and results. Eleven were round and six were rectangular. Alterations were made in grate area proportions, floor openings, flue design, and dimensions; the firing conditions and quality of ware obtained with each were recorded. The data obtained show effect on heat distribution and on time and fuel expenditures. Detail designs of flues are shown and the data are in tables and graphs. Detail specification and bill of materials are given for the 30-foot round kiln which was found to give best results in ware and costs.

I. Introduction

While there are other types of kilns which are more economical to operate than the periodic kiln, there will always be a place for the periodic kiln due to a relatively low first-cost, flexibility of operation, and other advantages which are well known. Periodic kilns are updraft, downdraft, and horizontal-draft. The downdraft kiln has a much wider use than the others. The chief advantages of the downdraft kiln are (1) the flame has a longer distance to travel and gives up heat more effectively, and (2) the hottest part of the kiln is the top. The first is readily understood because the flame travels from the fire box to the top of the kiln and from there to the collecting flues under the floor. The ware in the outer parts of the setting is heated up as the flame travels to the top of the kiln and the inner parts of the setting are heated as the gases of combustion travel down through the ware to the flues under the floor. In the case of either the updraft or the horizontal-draft kilns, the flames pass directly through the ware and out of the kilns. The second point is important in that the hottest part of the material in the kiln is in the position where it has the least weight to support and, therefore, it is not likely to become warped. (In updraft kilns, the hottest part of the kiln is nearest the fire box and in the lower courses of the setting. These often become crooked on account of the great weight of brick and other materials set above these courses).

Downdraft kilns may be further divided as between rectangular and round types. Lovejoy[2] states that the round, downdraft kiln is more used than any other type. The natural advantages of a round kiln are low cost per ton of capacity, better heat distribution, lower radiation losses, and simple bracing. The material and labor costs, on the basis of capacity, are lower than for a rectangular kiln because a circle

[1] This material was collected as a part of the requirements for the degree of Ceramic Engineer at the University of Illinois. Presented at the Annual Meeting, American Ceramic Society, Detroit, Mich., Feb., 1927. (Refractories Division.) Received December 27, 1926.

[2] Ellis Lovejoy, Burning Clay Wares, Second Edition, p. 199.

will inclose a greater area than any other shape of equal perimeter. The heat distribution can be more effective on a round kiln because the fire-holes are spaced equally around the kiln and at the shortest distance from the mass of ware set in the kiln. Radiation is proportional to the surface exposed and is, therefore, less for a circular-shaped kiln than for one of any other shape. The thrust due to thermal expansion being equally exerted in all directions in a round kiln, the only bracing required is bands which are simply fastened together at the ends.

As compared with continuous kilns of the chamber or car-tunnel type the round, downdraft kiln requires a much smaller first cost, or investment. The continuous kiln is more elaborate in construction because it is built on a larger scale of capacity than a single round kiln. Greater accuracy of design is necessary because of the larger mass of construction which must be proportioned to withstand the strain of high temperatures and continuous operation. The layout must be carefully planned in order that the control may be accomplished without too much complication. Where a variety of ware sizes is to be fired, or if the output is irregular, the flexibility of the round, downdraft kiln is a decided advantage, both in the amount invested per ton of capacity and in the cost of operation.

II. Development of Present Kiln

In the study and development of a proper kiln for firing refractories, data were taken on the construction and operation of a considerable number of kilns already in use for this purpose. A preliminary survey was made to determine necessary repairs. New fire arches were put in, flash walls straightened, floors leveled, and flues cleaned. Probably the cleaning of the flues was the most important of all as it was evident from their condition that little attention had been given to them.

The following data were taken from the various kilns:

Furnaces: (1) type of grate (whether inclined or flat), (2) number of furnaces, (3) width, (4) height (bottom of ashpit to top of arch), (5) depth (outside of kiln to flashwall), (6) length of grate bars, (7) approximate grate area per grate (width times effective length), (8) height of flashwall (from bottom of ashpit), (9) height of flashwall (from top of grate bars), (10) size of throat (opening at top of flashwall), (11) area of all throats.

Interior: (1) height from floor to spring of crown, (2) height from floor to highest point of crown, (3) diameter of kiln between kiln walls, (4) diameter of kiln between flashwalls, (5) number of doors or wickets, (6) height of doors, (7) width of doors, (8) height of flashwall above floor, (9) distance of grates below floor level.

Floor: (1) number of floor openings, (2) size of floor openings, (3) area of floor openings, (4) area of floor.

Bottom: (1) type of bottom (whether entirely open, or partially solid, or with ring flue, etc.), (2) size of secondary flues,[1] (3) area of secondary flues, (4) number of secondary flues, (5) size of primary flues,[1] (6) area of primary flues, (7) number of primary flues, (8) number of secondary flues to each primary flue, (9) number of primary flues to each stack flue, (10) number of stack flues.

Stack Flue: (1) size of flue to stack, (2) area of flue to stack, (3) length of flue to stack, (4) number of curves, (5) position of drier connection.

Summary: (1) area of grates in per cent of floor area, (2) area of throats in per cent of floor area, (3) area of floor openings per cent of floor area, (4) area of secondary flues per cent of floor area, (5) area of primary flues per cent of floor area, (6) area of flue to stack per cent of floor area.

Discussion of Data The kilns, seventeen in number, were all down draft, and of the periodic type. Not more than two kilns were connected on the same stack. Eleven kilns (1, 2, 3, 4, 5, 6, 8, 10, 15, 16, and 17) were round, and six (7, 9, 11, 12, 13, and 14) rectangular. This difference in shape is indicated in Fig. 1 together with other data. The furnace grates were flat or inclined (Table I) and five different styles of bottom were in use (Table I and Fig. 2). The flues leading to the stacks were low and narrow, as may be judged by referring to the cross-sectional areas as shown in Table I.

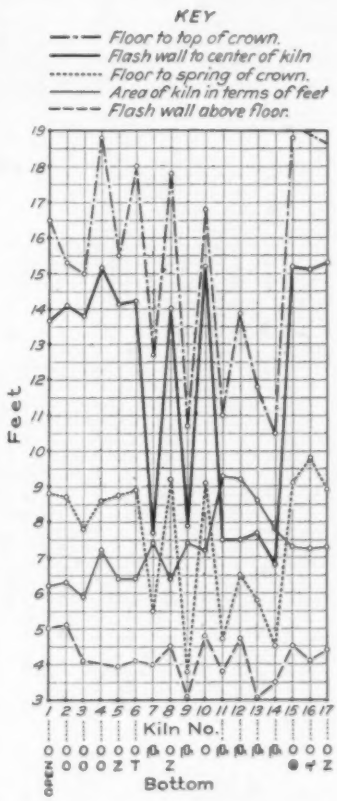

FIG. 1.—Relation of flashwall weight to governing factors.

The variety of dimensions is shown in Fig. 1. The floor area of the round kilns varied from 580 square feet for kiln 3 to 920 square feet for kiln 11. With exception of kilns 1, 2, and 3, which were used for small ware, the average capacity of the kilns studied was about 225 tons of brick and other refractories. Kilns 5 and 6 held slightly less and some of the rectangular kilns held more. However, no particular difference in results of operation was

[1] Starting with the flue leading to the stack, a *primary* flue is the flue (or flues) which connects the stack flue with the underfloor flues. The *secondary* flues are those which connect the floor openings with the primary flues.

noted between the 28- and 30-foot round kilns which might be charged directly to the size or area.

The height from the floor to the spring of the crown was fairly constant at about 8 feet 6 inches, although for kiln 3 the dimension was 7 feet 10 inches and for kiln 16, 9 feet 10 inches. The great variation in the height from the floor to the highest point of the crown, when considered with the height of the spring of the crown, indicates several types of crown design from the flat (about 25% rise) to those which approached the semicircular. The regular procedure was to set only 28 to 30 courses high (each course 4½ inches high) and this did not require a particularly high crown. Round kilns with a spring of 6 to 8 feet were amply high. Because there appeared to be no difference in the kilns with high crowns and those with flat ones, except that the former buckled and failed more readily than the latter, the semicircular type was replaced by lower crowns whenever a new crown was built.

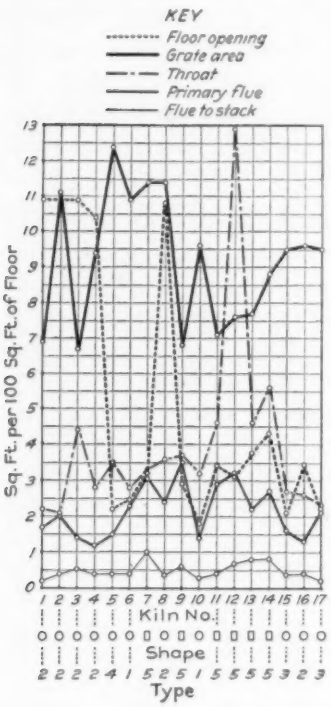
KEY
Floor opening
Grate area
Throat
Primary flue
Flue to stack
Sq. Ft. per 100 Sq. Ft. of Floor
0 1 2 3 4 5 6 7 8 9 10 11 12 13
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
Kiln No.
Shape
2 2 2 2 4 1 5 2 5 1 5 5 5 5 3 2 3
Type

FIG. 2.—Heat canal chart.

The height of flashwall varied without reference to size or type of kiln. The relative importance of the data given is shown in Fig. 2. The types of bottom are shown in Fig. 3.

Complete records of each firing were made covering the following: (1) Kiln number, (2) firing number (a consecutive number used as an additional check on the performance), (3) date fired, (4) largest ware set and condition of ware as to whether or not it was dry, (5) temperature readings at three-hour intervals, (6) draft readings at eight-hour intervals, (7) notes regarding weather and other information affecting the firing, (8) cones used, (9) condition of trials drawn, (10) notes on the progress of the last stages of the firing (whether the kiln was finished evenly, etc.), (11) location of cracked ware and causes, (12) location of light-fired material and causes, (13) location of other irregularities and causes.

The data obtained allowed one to see the treatment given each kiln on every firing, and the results. From this it was possible to observe kilns which performed satisfactorily and plan for changes in others to bring them to a better production of first class ware.

TABLE I

Kiln Number	1	2	3	4	5	6	7	8	9	10
Type (x)	O	O	O	O	O	O	R	O	R	O
Diameter (ft.)	28.1	28.1	27.2	30.3	28.55	28.3		28.55		30.05
Width (ft.)							15		15	
Length (ft.)							50		50	
Type bottom (xx)	2	2	2	2	4	1	5	2	5	1
No. fire boxes	10	10	10	10	10	10	12	10	16	10
Type (xxx)	I	F	F	F	F	F	F	F	I	F
Width (in.)	18	24	24	24	27	24	24	24	18	24
Height flashwall (ft.)	5.0	5.1	4.1	4.1	4.0	4.1	4.0	4.5	3.1	4.8
Areas (sq. ft.)										
Floor	620	620	580	720	640	630	.740	640	740	710
Grate	42.8	68.9	38.8	70.0	78.6	68.6	84.3	73.0	50.3	68.2
Throat	13.6	13.0	25.5	20.2	22.4	17.0	24.4	23.0	28.1	22.7
Floor openings	67.6	67.6	63.2	75.0	12.9	15.7	23.7	69.0	21.4	12.8
Secondary flues	26.3	26.0	35.0	36.7	6.8	—	—	34.7	—	—
Primary flues	10.5	12.4	8.1	8.6	9.7	14.5	22.9	15.4	25.9	9.9
Stack flue	1.4	2.5	3.2	2.9	2.7	2.4	6.8	2.2	4.7	2.1
Per cent of floor area										
Grate	6.9	11.1	6.7	9.7	12.3	10.9	11.4	11.4	6.8	9.6
Throat	2.2	2.1	4.4	2.8	3.5	2.7	3.3	3.6	3.8	3.2
Floor openings	10.9	10.9	10.9	10.4	2.3	2.5	3.2	10.8	2.9	1.8
Secondary flues	4.2	4.1	6.0	5.1	1.1	—	—	5.4	—	—
Primary flues	1.7	2.0	1.4	1.2	1.5	2.3	3.1	2.4	3.5	1.4
Stack flue	0.22	0.40	0.55	0.40	0.42	0.38	1.06	0.34	0.64	0.30

x —O = Round; R = Rectangular
xx —See Fig. III
xxx— I = Inclined; F = Horizontal

ABLE I

8	9	10	11	12	13	14	15	16	17
O	R	O	R	R	R	R	O	O	O
28.55		30.05					30.5	30.3	30.05
	15		15	15	15	15			
	50		60	60	60	60			
2	5	1	5	5	5	5	3	2	3
10	16	10	20	20	20	20	10	10	10
F	I	F	I	I	I	I	F	F	F
24	18	24	18	18	18	18	24	24	24
4.5	3.1	4.8	3.8	4.75	3.1	3.4	4.6	4.1	4.4
640	740	710	920	920	850	780	730	720	710
73.0	50.3	68.2	65.3	70.0	65.4	68.6	69.4	74.2	67.5
23.0	28.1	22.7	42.3	118.7	39.1	44.5	19.7	18.7	16.3
69.0	21.4	12.8	31.3	28.5	33.2	33.5	15.3	24.5	14.9
34.7	—	—	—	—	—	—	9.7	29.0	8.1
15.4	25.9	9.9	26.7	29.4	18.7	21.8	12.4	9.4	15.6
2.2	4.7	2.1	3.9	6.6	7.1	6.5	3.0	3.2	1.6
11.4	6.8	9.6	7.1	7.6	7.7	8.8	9.5	9.6	9.5
3.6	3.8	3.2	4.6	12.9	4.6	5.7	2.7	2.6	2.3
10.8	2.9	1.8	3.4	3.1	3.9	4.3	2.1	3.4	2.1
5.4	—	—	—	—	—	—	1.3	4.1	1.1
2.4	3.5	1.4	2.9	3.2	2.2	2.8	1.7	1.3	2.2
0.34	0.64	0.30	0.42	0.72	0.84	0.83	0.41	0.44	0.22

= Rectangular

= Horizontal

The next step was to plan for the changing of the more radical designs. (Only a few data were required to show the need of some corrections). The final step was to work out a set of standard dimensions from the performance records which were accumulating.

Basis of Comparison

In determining the basis of comparison it was decided to use the firing time and the per cent No. 1 ware. The length of firing affects the capacity of the kiln through the turnover, the cost of labor for firing, and the amount of coal used. The percentage of first-class ware produced is the other measure of kiln efficiency. The time required for a complete cycle for any kiln consists of the firing and cooling times, and the time required to set and draw. It has been my experience that kilns of this type can be turned in about 15 days. The time is made up as follows:

	Days
Firing	5½
Cooling	5½
Drawing	2
Setting	2

From this it will be seen that an increase of one day in the firing on a basis of 15 days will reduce the capacity one-fifteenth or about 7%. That the cost of firing is proportional to the length of firing is plain and approximately the same applies to the coal consumed. The daily consumption does not vary a great deal whether the heat progresses or the kiln "balks" in the final stages of the firing. An approximate coal consumption for a round kiln set with 200 tons of refractories is 50 tons. It will be used as follows:

Period (hours)	Temperature Rise	Coal Used
0– 24	0– 160°F	1 ton
24– 48	160– 460	4 "
48– 72	460–1000	8 "
72– 96	1000–1600	12 "
96–120	1600–2100	15 "
120–132	2100–finish	10 "
Total time, 132 hrs.		Total coal, 50 tons

From this it is evident that an increase in the first stages of the firing will not affect the coal consumption. A day longer in raising the temperature to 460° would increase the amount of coal used two tons, or about 4%, while increasing the total time 24 hours, or about 18%. However, a day longer in bringing the kiln from 460° to 1600° would increase the coal consumption 10 tons, or about 20%, as compared with an 18% increase in the time. It has been my experience that at first the firing time was long on account of long finishing periods. This was due to small flues. Later, when the flues had been enlarged so that the finishing period could be speeded up, it was thought to decrease the firing time still further by shortening the water-smoking period. The result of this procedure, when carried to an extreme, was that longer intermediate and high fire periods were necessary to properly distribute the heat and finish the firing. The

final outcome has been a schedule as shown above in which the temperature is raised gradually to the finishing period. The final period is then accomplished without delay due to the fact that the ware is heated uniformly in all parts of the kiln. It is thought that a complete record of firing times would serve as a check on capacity, labor cost, and coal consumption.

The quality of the ware drawn is also an important unit of measure. This is shown in the percentage of first class ware produced and was of particular use in the study of floor and flue construction. The areas of light-fired ware were reflected as other than first class ware and resulted in increased costs for sorting and refiring.

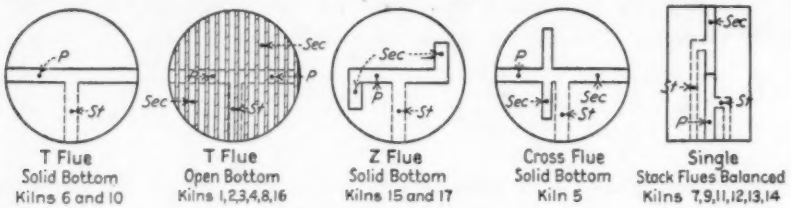

FIG. 3.—Kiln bottoms.

The two units of measure were the most important and best suited from the factory standpoint because they indicate costs and quality. Long firing times show that costs are increasing due to extra coal and labor being used and to lower capacity on account of a longer turnover. Low quality results in higher costs because extra sorting is required, and less is produced per dollar spent for production.

Types of Furnace

The furnaces were of two types, flat grate and inclined grate. There is considerable difference of opinion as to the merits of the two. Greaves-Walker[1] gives four requirements for any kiln furnace as follows: (1) that it will burn ordinary or low grade fuel, (2) that it can be operated by common labor, (3) that it is easily possible to obtain either oxidizing or reducing conditions, and (4) that the cost of upkeep is low.

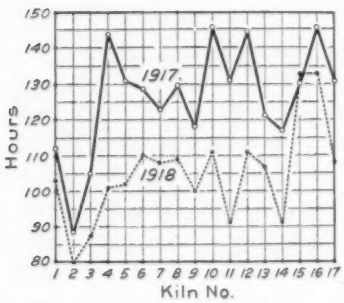

FIG. 4.—Average firing time by kilns.

The coal used in this district generally is southern Illinois run-of-mine. The amount of coal used and the length of firing did not vary noticeably in kilns equipped with the different furnaces. The graphs in Fig. 4 are made up of yearly average firing times for 1917 and 1918. The average for the whole group for 1917 is about 130 hours and there are some flat grate kilns above and some below that figure.

[1] A. F. Greaves-Walker, Clay Plant Construction, p. 101.

TABLE II

Kiln No.	1		2		3		4		5		6		7		8		9		10		11
	B	Q	B	Q	B	Q	B	Q	B	Q	B	Q	B	Q	B	Q	B	Q	B	Q	B
First Quarter 1917							185	—	157	—	172	—	148	—	129	—	157	—	212	—	147
							180	—	265	—	162	—	275	—	177	—	168	—	219	—	252
							144	—	216	—	144	—	144	—	162	—	141	—	180	—	141
							165	—					120	—			129	—			138
Second Quarter 1917							120	93	132	95	161	99	132	—	150	—	123	—	222	84	149
							173	97	120	97	145	97	146	95	164	99	175	96	157	—	130
							181	95	133	98	121	98	159	97	132	94	155	94	145	—	120
							147	94	105	98	120	98	99	97	154	98	152	96	108	99	144
															141	98	144	98			
Third Quarter 1917	87	100	93	99	84	100	156	—	96	98	105	98	93	93	126	96	114	93	108	96	114
	129	100	81	100	156	100	93	96	102	97	129	95	84	94	102	97	105	89	96	97	132
	—	100			81	100	93	98	120	96	108	94	102	96	114	93	129	90	108	90	117
					105	100			120	93	126	98	78	90	84	92	96	97	105	95	132
									78	94	105	88							108	80	96
Fourth Quarter 1917	123	—	90	—	102	100	105	70	102	94	120	—	78	85	96	91	81	97	129	98	120
	114	97			108	100	156	30	114	97	120	72	129	75	126	93	120	96	180	59	96
	108	100			96	100	120	96	144	6	132	84	120	60	126	88	96	91	150	82	102
							144	95	96	89	105	93	117	85	108	93	108	95	120	94	96
									120	89			108	94	117	47	120	95			
													96	96			126	93			
First Quarter 1918	120	100	—	100	84	100	132		96	52	105	93	132	56	108	81	126	76	108	91	105
	96	97	84	98	95	100	126	84	105	80	120	77	129	95	132	75	126	64	120	100	96
	84	100	78	99	72	—	99	97	81	96	120	96	102	97	108	85	96	92	120	62	84
	78	100	60	100	72	100	93	88	108	96	108	70	93	98	96	97	84	91	108	92	96
	72	100	72	100	66	100					108	98	96	92			84	96	96	92	90
	108	100	54	100	60	100											96	95			
	72	100	54	71	72	71															
	81	100	57	100																	
Second Quarter 1918	105	98	96	89	66	100	84	98	96	96	84	94	105	94	105	95	96	96	102	96	84
	105	100	102	98	72	95	105	94	105	94	105	95	96	92	120	98	93	93	117	95	84
	96	92	72	100	81	100	102	97	108	97	117	92	96	96	96	84	96	97	105	94	87
	120	99	84	100	78	98	96	94	108	95	105	97	105	89	102	84	96	93	96	97	72
	93	99	81	80	81	99							96	87	84	95	105	92			
			72	100	96	88															
Third Quarter 1918	84	96	72	100	96	98	90	93	105	86	117	94	96	95	96	96	96	97	96	99	72
	84	99	72	98	84	88	93	87	96	98	105	98	96	97	93	96	90	96	108	97	84
	132	100	72	63	72	76	69	92	108	89	111	100	96	96			90	89	99	94	82
	114	90	72	100	126	100	81	95	93	90	75	91					93	88			
	87	95	54	84	81	92															
			84	88	96	80															
Fourth Quarter 1918	102	94	78	97	84	95	84	94	105	90	108	95	108	85	102	91	120	84	108	99	105
	144	94	108	80	90	91	120	86	114	98	90	77	132	86	108	80	108	71	153	96	129
	126	97	114	97	114	99	114	94	120	48	108	98	108	58	177	83			102	65	
	129	94	105	85	120	84	108	91	90	99	177	78	138	82					141	91	
	144	90	108	91	105	97	117	91					132	95							
			105	89	102	91															
First Quarter 1919	120	82	96	79	102	94	108	88					132	80			120	93	162	79	102
	120	84	102	76	102	90	105	97					120	85			120	80	120	85	96
			93	95	96	96											123	78	153	92	117
			96	88													132	90			132
																					117
Second Quarter 1919			93	99			120	88	144	79							132	94	180	89	120
							135	88									126	95	152	89	111
							111	94									129	94			105
																					105

B = Firing time in hours
Q = Quality per cent

9		10		11		12		13		14		15		16		17	
B	Q	B	Q	B	Q	B	Q	B	Q	B	Q	B	Q	B	Q	B	Q
157	—	212	—	147	—	193	—	152	—	119	—	171	—	177	—	240	—
168	—	219	—	252	—	150	—	119	—	204	—	195	—	162	—	189	—
141	—	180	—	141	—	144	—	126	—	135	—	153	—				
129	—			138	—	168	—	129	—								
123	—	222	84	149	95	146	93	150	—	120	—	129	—	126	—	132	97
175	96	157	—	130	95	157	90	149	97	128	95	133	98	171	97	125	98
155	94	145	—	120	—	142	89	138	97	135	96	149	96	160	97	146	—
152	96	108	99	144	—	144	91	156	97	138	96	156	—	150	—	114	98
144	98							141	95	120	98			174	99		
										120	94						
114	93	108	96	114	93	111	79	96	98	108	98	153	97	177	87	90	96
105	89	96	97	132	91	108	89	108	94	108	96	96	98	144	96	108	96
129	90	108	90	117	92	156	96	105	96	96	87	105	97	96	96	132	98
96	97	105	95	132	97	153	74	108	95	120	88	105	91				
		108	80	96	95	138	74	105	91	84	94						
81	97	129	98	120	86	129	87	105	95	96	94	123	—	96	88	81	77
120	96	180	59	96	74	147	73	93	84	108	—	105	73	117	—	102	96
96	91	150	82	102	77	126	93	120	73	114	75	120	84	196	63	165	46
108	95	120	94	96	82	129	96	105	97	96	82	102	91	108	91	102	97
120	95							96	96	108	95	96	94	129	97	96	98
126	93									96	95						
126	76	108	91	105	97	132	87	96	90	120	96	132	71	120	71	117	95
126	64	120	100	96	97	—	89	120	67	84	89	132	95	204	97	105	82
96	92	120	62	84	95	108	92	108	98	84	96	96	92	114	83	108	99
84	91	108	92	96	95	120	95	96	96	96	93					108	—
84	96	96	92	90	94	108	85									96	91
96	95					108	88										
96	96	102	96	84	98	111	97	96	96	105	97	129	94	105	98	96	97
93	93	117	95	84	96	108	82	120	88	90	94	117	85	108	98	105	96
96	97	105	94	87	94	105	85	108	89	84	98	138	94	123	97	108	96
96	93	96	97	72	86	129	91	96	98	96	98	150	92				
105	92																
96	97	96	99	72	89	72	100	96	94	84	98	156	99	120	89	108	98
90	96	108	97	84	59	81	100	105	97	96	95	123	95	144	97	114	99
90	89	99	94	82	85	93	100	105	95	69	90			120	91	120	94
93	88					102	99	81	80	102	89			141	92	132	95
						99	85	120	83								
120	84	108	99	105	71	129	84	108	95	96	99	129	96	138	79	120	97
108	71	153	96	129	93	117	88	96	82	108	75	126	54	120	95	93	71
		102	65			141	88	132	90	72	81	150	80	156	96	144	67
		141	91			141	91	132	88	132	94	141	67				
120	93	162	79	102	75	129	94	108	100	96	100	153	87	141	96	132	81
120	80	120	85	96	79	138	87	117	96	96	95					129	79
123	78	153	92	117	72	153	86	117	68	117	83					144	97
132	90			132	79	150	96	108	64	108	92					138	95
				117	85	156	83	144	68								
132	94	180	89	120	86	138	89	141	95	141	82	138	90	150	93	120	95
126	95	152	89	111	97	129	94	101	92	129	96					120	98
129	94			105	96	177	96	129	95	141	96					156	96
				105	98	147	95	120	96	126	95						

ime in hours
per cent

The same is true of the inclined grate kilns, and of both for 1918. Kiln 11 had an average performance for 1917 with inclined grates and did much better in 1918 with flat grates. The entire improvement cannot be charged to the change in type of grate, however, because the kiln was entirely rebuilt and many other changes were made.

This is the only instance where the number of furnaces was changed on any kiln. Originally there were twenty inclined grates on kiln 11. On rebuilding they were changed to flat grate fireboxes and only eighteen were used. While it is true that kilns 9 and 14 had a lower firing time than the other kilns in the group, this could hardly be considered as the result of more furnaces per kiln because they are rectangular and cannot be compared directly with round kilns.

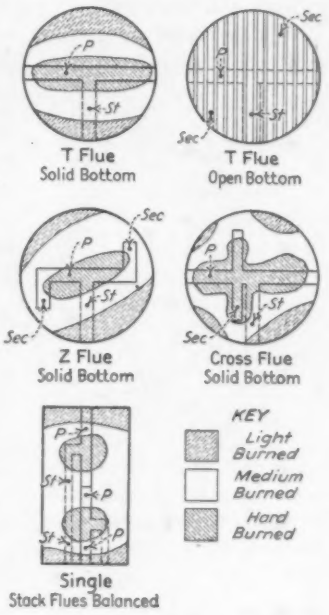

FIG. 5.—Firing results of various types of bottoms.

Both types of furnaces were operated with the same class of labor, but the advantage is with the flat grate in this because it is entirely enclosed and the workman is protected from the heat of the furnace. Where the man must stand before the furnace for ten or fifteen minutes to clear out the clinker and charge fresh fuel, this matter of protection is important. An honest attempt to put the fire in good condition is much more likely if the fireman can be protected from the heat while working.

Air for combustion is admitted through the door of the furnace (flat grate) and passes over the fire. The sheet iron cover (detailed in kiln drawings Fig. 7) is never used except when clinkering while the kiln is on fire and the amount of opening is regulated with a shovel or two of coal. The theory of the inclined grate is that it operates like a simple gas producer with the air passing over the top of the fuel bed. In this district (St. Louis) the general practice is the use of inclined grates, but I have observed that the ware drawn from kilns having flat grates is clearer and more nearly free from iron spots than that from inclined grate kilns. The iron spots develop readily in clay of the Cheltenham district if fired under a reducing, or alternate oxidizing and reducing condition. The reason for the freedom from

iron spots in flat grate fired kilns, I believe, is that they can be controlled to give uniformly oxidizing conditions. If this is true then they fulfill the third requirement of Greaves-Walker[1] in regard to control of kiln atmosphere.

If one type was very complicated as compared to the other, it might be assumed that the former would have higher maintenance costs, but since both types were comparatively simple no comparison of the cost of upkeep was made.

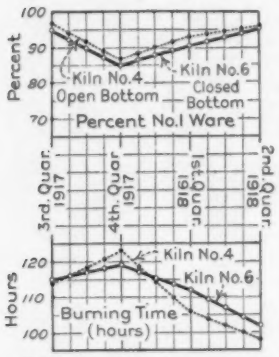

FIG. 6.—Relation between open and solid bottom kilns in regard to per cent No. 1 ware and firing time

After a wide and careful observation, Greaves-Walker[1] has sketched a furnace which fulfills the specifications. It is of the flat grate type and similar to the one which is detailed in the kiln drawings attached (Fig. 7). It has been my experience that the flat grate is preferable due to the matter of control and this is no doubt influenced by the fact that the fireman is protected while working. The castings used will last indefinitely, the fire hole is simple to construct, and requires no more replacement than the inclined grate.

Area of Grate Surface

The particular point studied in connection with furnaces was the area of the grates and a saving in the time of firing was accomplished when these were enlarged from 8 to 10% of the floor area. Two examples of this are kilns 3 and 11. During the latter part of 1917 the grate area of kiln 3 was increased from 6.7 to 12.0%, and the average firing time dropped from 105 to 87 hours for the year 1918. The grate area of kiln 11 was increased from 7.1 to 15.4% with a decrease in firing time from 131 hours (1917) to 92 hours (1918).

Greaves-Walker[1] suggests that 12½ to 25 sq. ft. is the proper ratio of grate area per 100 sq. ft. of floor area. Lovejoy[2] recommends 15% of the floor area as the grate area for firing to cone 10. In our study we found that some kilns fired well with from 8 to 10% grate area. (Kiln 9 with 6.8% grate area had a slightly longer firing time than kiln 14 with 8.8% area.)

TABLE III

	Average Firing 1917	Average Firing 1918	Average Firing 1919
Kiln 9	118 hrs.	110 hrs.	125 hrs.
Kiln 14	117 "	91 "	118 "

[1] A. F. Greaves-Walker, *loc cit.*

[2] Ellis Lovejoy, Burning Clay Wares, Second Edition, p. 148.

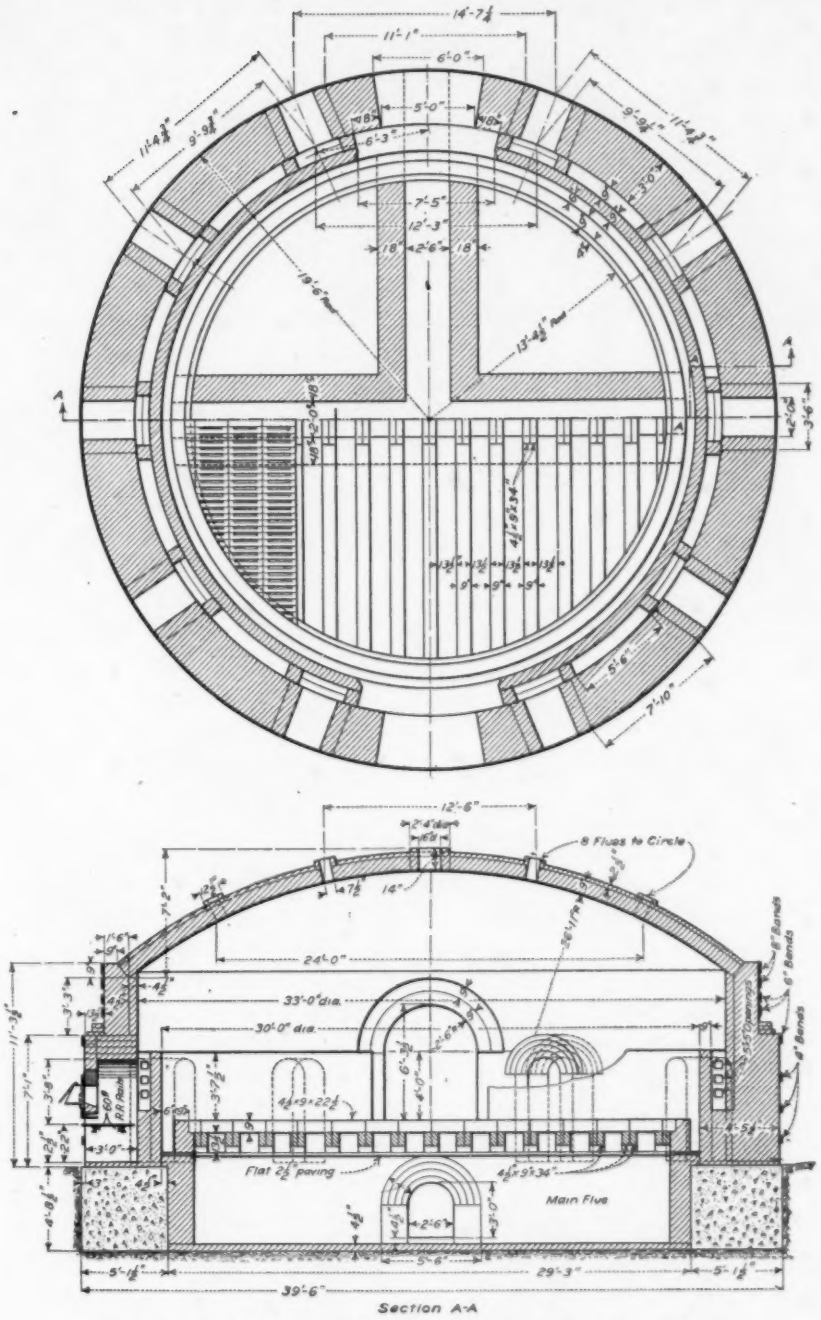

FIG. 7.—Design of round downdraft kiln for firing refractories

Either set of averages compared very well with other kilns of larger area during the same period. (See Fig. 4).

Throat Area The throat opening was of the same construction in all kilns and similar to the kiln drawing shown (Figs. 7 and 8). The variation in Table I was due to the pushing in of some of the flashwalls of the fire holes. This narrowed the throats until repairs could be made. No comparison of throat area was made.

In a kiln, having a flashwall built at least fifteen inches above the first (lower) ring of arches in the fire hole, there was found to be an excessive amount of light-fired ware. This was located at the base of the wall and extended around the kiln. The height of the wall was cut down to a point just above the first ring of arches with the result that the amount of light-fired ware was reduced. Later experiments have indicated that extremely high flashwalls tend to retard the progress of the firing. Another disadvantage of a high wall is that the space between it and the kiln wall is likely to become filled with broken material. This has a tendency to push over the wall due to the thrust of thermal expansion. It is rather difficult to observe the condition behind a high wall, whereas a low wall can be inspected conveniently and cleaned without any particular effort. From this it would seem that the proper height of flashwall is that which will just clear the lower ring of the arches of the fire hole.

Kiln Floors The floor opening was taken as the total opening between the floor tile when the kiln was empty. While this is not the opening when the kiln is filled with ware, the actual opening would be proportional in kilns of the same type. In filling all kilns the ware was set in regular rows without regard to the floor openings. The net floor opening in "solid" bottom kilns (Fig. 3, *1, 3, 4 and 5*) would be proportional to the total space between the tile, although that could not be compared directly with "open" bottom kilns. (Fig. 3, *2*). The important item in this connection is the better distribution of heat which is discussed later.

The four kinds of "solid" bottoms are illustrated in Fig. 3. There are no floor openings except over the main flues of the kiln.

Type 1, Fig. 3, is the simplest type of bottom for a round kiln. The open flue extends entirely across the kiln and is at right angles to the flue to the stack. Floor tile cover the flue and the balance of the floor is paved. In filling the kiln flues are built in the setting at right angles to the open flue. (In order to have the setting standardized, the one method of building flues through the setting was used for all kilns). It was thought that this method of setting would permit the kiln to operate the same as more elaborate systems, *i.e.*, the products of combustion collected by the flues in the setting would be passed along to

the open flue. The fire holes were fired evenly, but a hot spot developed over the open flue. In order to even up the heat throughout the kiln, the damper was lowered in the stack flue toward the finish of the firing and the fires held for a long period to "soak" the heat to the outer parts of the setting. When drawn, it was found that the ware was unevenly fired, as shown in Fig. 5. This was due to the extremely strong draft over the open flue which had pulled directly through, instead of working through the cross-flues built in the setting. Once a hot spot developed, no amount of "soaking" could even up the heat through the kiln. Over the top of the setting the material was all hard-fired but the lower part was fired as shown. The ware set over the open flue was extremely hard and in some cases warped. The outer parts of the setting were light and usually had to be refired. In order to operate this type of bottom with any success, it was necessary to fire the furnaces at the ends of the open flue more lightly than the others. By firing the remaining fire holes in the regular way while holding back on the two nearest the flue and "soaking" at the finish it was possible to obtain a fairly uniform firing. This method of firing, however, resulted in a longer firing time. (Table IV.)

While the action of a type 3 bottom differs from type 1, the results are about the same except that the zone of light ware is moved around about 45° on account of the change in flue arrangement. The style of bottom is such that two furnaces nearest the flue on each side must be held back to prevent the development of a hot spot. If the flues in the setting are built at right angles to the secondary flues, the draft is not sufficient to pull the heat through the setting because the stack pull is "short circuited" from the furnaces directly into the main flue. This is possible because the rows of material are parallel to the main flue, and the space between rows will usually come directly over the main flue. This space will offer little resistance to the products of combustion as compared to that offered if the gases traveled through the flues of the setting as intended. If the flues in the setting are built at right angles to the main flue, then the same thing will occur over the smaller flues if the space between the rows coincides with an open flue. The result in either case is a very hard firing over the open flues, a light firing at the outer parts of the kiln, and all variations between the two throughout the kiln.

About the same results are obtained with the bottom shown in Fig. 3, type 4. A hard firing is obtained over the open flues and a light firing in the areas not served with kiln flues. The fire holes at the ends of the flues must be held back as described above if any degree of uniformity is to result.

The rectangular bottom illustrated (Fig. 3, *5*) has the strongest draft where the stack flues open into the main flue which extends the full length of the kiln. This is true when the kiln is filled with ware, because, unlike the round kiln, it is not possible to pile up a greater depth of ware over these openings. The cross-section of the setting of a rectangular kiln is the same in relation to the open flue whether the section is taken at the center or over the stack flue opening. With an inequality of draft, the only means of firing off a kiln of this type is by a manipulation of the fires. The furnaces at the ends and center must be kept ahead of the furnaces opposite the openings to the stack flue. This is done by more frequent cleaning and heavier firing. In addition, it was advisable to "soak" the kiln in the final stages of the firing. When drawn, the ware was found to be very light at the wickets, hard over the stack flue openings, and medium fired through the center of the kiln. The difference in quality between the ware in the center of the kiln and at the wickets was due to the cooling effect of the outside atmosphere on the ware near the kiln doors.

It is evident that changing over to an open bottom similar to type 2, Fig. 3, would not make any important improvement in the performance because the point of greatest draft would be the same. The objection to a rectangular kiln of this type is that it is not possible to equalize the draft.

If a cross-section of a round kiln of the open bottom type, Fig. 3, *2*, is taken through the center of the kiln, it will be noticed that the setting is highest directly over the center part of the kiln. In the bottoms sketched, the stack flue opens into the main flue at this point. It will be seen that the greatest frictional resistance to gases of combustion is offered at the part of the kiln which has the greatest draft. At the points where the setting offers the least resistance to the draft (around the flashwall) the draft is also at the minimum. As the stack pull increases toward the center of the kiln the thickness of the setting also increases and in that way the draft is equalized over the entire kiln.

It may be said that the draft at the extreme ends of the primary flue would be stronger than at a point 90° removed and that is true theoretically. However, there will always be variations in the spacing of the setting due to the difference in size of ware set and to the human element which will more than offset the final exactness of heat distribution. It is hardly to be expected that so exact a regulation could be worked out as to eliminate the necessity for the experience of a head burner. His knowledge will indicate which furnaces are working the best and which lag behind, due to slight inequalities of draft within the kiln. He will regulate the furnaces as the firing proceeds to heat up the ware uniformly so that no time will be lost in evening up at the finish.

It was my experience that the open bottom kilns could be fired uniformly and finished quickly. The ware had a better appearance because the kiln could be brought through the different stages of firing without any lost time. There was no lag in the firing schedule during the water-smoking period and for that reason the ware did not have that soft, spongy look, which might have appeared if the steam had been retarded in passing out of the kiln. The oxidation and finishing periods were carried on with a regular temperature rise and the result was clear ware of a uniform color. The material set toward the top of the kiln was harder fired than the bottom, but there was no wide variation as was so pronounced in solid bottom kilns. (The "soaking" period is usually carried on under reducing conditions and this results in dark-colored ware.)

Length of Firing Period

The difference in firing time between open and solid bottom round kilns is shown in Fig. 6. This data (Table IV) seems to bear out the statements that a longer time was required for firing due to the fact that the different furnaces had to be forced or banked and a soaking period allowed in order to bring the ware to about the same finishing temperature. The data is as follows:

TABLE IV

	Kiln No. 4		Kiln No. 6	
	Firing Time	No. 1 (per cent)	Firing Time	No. 1 (per cent)
3rd Quar. '17	114 hrs.	96.9	115 hrs.	94.5
4th " '17	123	87.2	119	85.1
1st " '18	106	92.5	112	90.5
2nd " '18	98	96.1	102	94.8

The higher percentage of No. 1 ware produced in kiln 4 was due to the uniform firings which were possible with the open bottom.

Flue System

The size of the midfeather flues is determined by the height of narrow wall (9-inch) which will stand erect under the conditions of heating and cooling under load, the actual area needed for the products of combustion, and a reserve in which sand can accumulate for several firings without being removed. A low wall holds shape and position better than a high one, although the latter would allow a greater quantity of sand to accumulate before cleaning is necessary. No particular comparison was made of the secondary flue area. In practice, it is usually necessary to clean the center flue about every eight firings and the capacity of the secondary flues, as shown, is sufficient to accumulate sand for that period without clogging and interfering with the firing of the kiln.

While it is probably not essential to maintain the full cross-sectional area shown in our design for the main or center flue, it makes for simple

construction. It is easily kept up and that is one of the purposes of the design.

A comparison of the firing times for 1917 and 1918 will indicate the result of increasing the area of the stack flue to about 1% of the floor area. During the latter part of 1917 every flue to stack was enlarged except the flues of kilns 7 and 13. In every case the firing time for 1918 averaged lower than for 1917. While the changes in kiln bottoms were important from the standpoint of heat distribution, the only important area change was in the flues leading to the stack. Therefore, it seems correct to conclude that the enlarging of the flues to the stack resulted in shorter firing times.

Summary of Results from Operation Studies

Thus, it will be seen that the essential parts of the round kiln described herein have been worked out on the basis of performance. It was found that the furnaces with flat grates were simple to build, comfortable to work, easy to control, and satisfactory as to firing time. The flashwall height was determined by actual experiment. It was found that it need be only as high as the first ring of arches in the furnace.

The kiln bottoms were checked as to heat distribution and, as a result, the open type is recommended. The secondary flues are designed to withstand the movement of the floor due to expansion and contraction. The main flue is of substantial design. A cross-sectional area of 1.0% is recommended for the flue to the stack.

The following dimensions are suggested for a satisfactory round kiln for firing to cone 10:

Floor area 700 sq. ft.
Grate area 60 to 70 sq. ft. or 8–10% of floor
Throat area 20 sq. ft. or about 3% of floor
Floor opening 70 sq. ft. or about 10% of floor
Secondary flue 35 sq. ft. or about 5% of floor
Primary flue 10 to 20 sq. ft. or 2–3% of floor
Stack flue 7 sq. ft. or 1% of floor

From such a kiln it is reasonable to expect a firing time of 132 hours' or less, a coal consumption of 0.25 tons of coal per ton of ware, and an output of 400 tons per month of which 96% will be No. 1 ware.

III. Kiln Construction

Drainage

The first consideration in the building of a kiln is the drainage. It is important that the ground around the kiln, the firing pits, and the flues be well drained. Damp flues retard the first stages of firing. This delay may result in the softening of the ware in the lower courses of the setting if the water vapor of water-smoking cannot be taken off on account of a retarded draft, due to wet flues.

The damage in such a case is often serious. One plan is to lay several lines of drain tile under the kiln below the level of the foundation. These are put in before the construction is started and connected to the regular sewer system. Where natural drainage is not possible, because the flues are deeper than the regular drains, it is best to provide a well which is 10–20 feet deeper than the lowest flues. Drains can empty into the well which should be pumped out into the regular drainage system as often as is necessary.

Foundation As is shown in the accompanying sketches, the foundation is slightly deeper than the main flue. While this may not be necessary in some localities, it is recommended[1] with the suggestion that it may sometimes be advisable to go even deeper. As shown, the foundation is wide enough to support the combined weight of the kiln and the load of ware. The latter need hardly be considered as it is directly over and supported by the filling inside the foundation. The concrete for the foundation can be made of a 1: 2: 4 batch of cement, sand, and gravel. It is best to turn it several times. When pouring into the forms, the most substantial wall will be obtained if a piece of 1 by 6 lumber, or some similar flat tool, is used to ram the mixture down along the edges of the forms. Where the batch is dumped directly into the center of the form, this ramming prevents the heavier parts from settling out and produces a dense and uniform wall for the full width of the foundation.

Masonry From this point the kiln is constructed entirely of fire brick. (In our case that is the logical thing to do because we manufacture fire brick only). There is another reason for this method *i.e.*, the brick are all the same size and there is little difficulty in tying the brick work together. In many cases red brick are used for the outer courses and because these brick are usually smaller than a standard fire brick, Greaves-Walker[2] emphasizes the need of care in building the two kinds together securely. A mud-process clay of a Missouri No. 1 grade is very satisfactory for kiln construction. It is fairly dense and resists weather better than the average building brick.

A fireclay mortar made up of about 50% ground brick and 50% raw clay, ground fine, is used for all work except the outer parts of the kiln which will be exposed to the weather. Here a cement mortar is used.

The best construction is obtained when one-eighth inch joints are used throughout with the exception of the arches and crowns. The proper method of building these parts is to dip the brick in a slop mortar and hammer them into place. It is hardly necessary to mention the

[1] Clay Products Cyclopedia, 1924, p. 142.

[2] *Loc. cit.*, p. 99.

importance of careful construction. On this depends the life of the kiln. A poor or inexperienced workman can lower the efficiency of a properly designed kiln and make necessary the complete overhauling in a very short time. Particular care in building which may increase the cost slightly will pay big returns in less frequent repairs and the consequent loss of production.

Fire Boxes The lower parts of the kiln walls are thick enough to completely inclose the fire boxes. Heavy construction around the fire holes reduces the heat losses due to radiation through the sides of the fire box. The final opening (width of the fire hole) is shown as 24 inches, but it is customary when erecting the walls to put in only the two outer rings of semicircular arches. These are built into the walls in a permanent fashion, leaving the fire hole opening 3 feet 6 inches wide. Later, when the walls have been completed the fire box construction is finished up. It should be noted that the permanent arches extend out beyond the line of the upper wall. This is an important feature in that it makes the hob over the fire box more nearly water-proof. In some kilns it is customary to stop the arch even with the outer line of the upper wall and finish out the hob by laying brick as close to the wall as possible without tying into the wall. The joint thus formed soon cracks and allows water to get through and into the fire box. The upper part of the wall consists of a wall proper 18 inches thick which is lined with a 4½-inch course of brick. This lining is tied into the outer wall as little as is possible for good construction. It is not required to bear the weight of the crown and serves only to protect the wall proper from the high temperatures of the inside of the kiln. Greaves-Walker[1] emphasizes this feature of construction.

Crown The crown should be started from skew brick off of the 18-inch wall. Harrop[2], as quoted by Greaves-Walker[1], seems to have approved the idea and it has worked out very well. The crown is built up of key, wedge, and square brick in 2½-inch layers. Each course is keyed into place before the next is added. The rise of the crown is 6 feet in span of 33 feet. The cooling holes are built by omitting one brick wide (4½ inches) by three courses (approximately 7½ inches) along the other dimension. The top and center of the crown is finished out with a special set of blocks. These pieces provide a quick and satisfactory method of completing the crown which would require the cutting and careful fitting of many brick.

To hold the cover tile in place over the cooling holes, a square brick is turned on edge in the platting course above and below the hole. The

[1] *Loc. cit.*, p. 99.
[2] *Loc. cit.*, p. 98.

platting is a flat course (2½ inches) of brick washed with a slush of cement and sand. After the first firings a re-washing will fill any cracks which have developed and give a weather-proof coating.

Banding The bands used are shown in the sketches and the bill of materials. A double band is used at the top of the wall to brace the crown. This is a safety measure in case one breaks. The bands immediately above and below the fire box opening serve to hold the castings in place as well as brace the hobs of the kiln. The 4-inch band below the grate bars helps to strengthen that part of the brick work which is usually neglected. The detail drawings show the manner of fastening the bands at the wickets. A sketch of the lugs used at the doors and for fastening the ends of the bands are also shown. The use of springs at the band fastenings works out very well. They allow some leeway before the full thrust of the kiln is put on the band. This is most important when a kiln is being heated up for the first time. Failure to keep the bands free to take the expansion of the new brick work may result in the breaking of the band or the development of cracks in the walls as the temperature rises. At other times, the closing of the springs often indicates to the man in charge the need of slacking the bands and in this way prevents damage which may result with the breaking of a band.

Flues The main flues are simple in design and for that reason are easy to maintain and keep clean. The flue across the center of the kiln is not closed. It is bridged over with tile which support the floor tile. The flue to the stack is entirely covered and has no connection with the collecting flues except through the cross flues. The space between these flues and the foundation walls should be filled with a rammed mixture of grog and fireclay mortar. The grog should be crushed to two inches and finer. The best results are obtained if a six-inch layer is put in and tamped. Over this is spread a mortar joint of fire clay; then another six-inch layer of grog is put down, tamped, and mortared. If the entire fill is put in this way there is little likelihood of shrinkage and consequent unevenness of the kiln floor. Over the fill is placed a paving of brick on the flat which serves to level up for the building of the midfeather flues.

These flues are built at right angles to the center flue which is spanned with tile. The floor tile are set directly on the walls of the midfeather flues without a mortar joint. The tile are placed as close together as possible and no expansion joint is provided except around the edge of the floor at the base of the flash-wall. At this position a nine-inch wall is built up to the level of the floor leaving a space six inches wide between the wall and the flash-wall. This expansion ring is filled with sand to prevent it becoming filled with broken material when the kiln is in use.

Fire Box Lining At this stage of the construction the nine-inch lining of the fire boxes is put in. As shown in the drawings, a nine-inch wall is also built across the front of the furnace. The purpose of this is to protect the firebox castings. The building of the flashwall and the placing of the firebox castings marks the completion of the work. The height of the flashwall is determined by the height of the first (lower) ring of the fire arch. Since the purpose of the flashwall is to divert the flame upward, it usually does not need to be any higher than the first rings of the fire hole. Any increase in height tends to choke the gases entering the kiln and increase the difficulty of keeping waste materials from accumulating behind the wall.

Bill of Materials The following is a list of the materials required for the building of a 30-foot, round, downdraft kiln:

Foundation		Crown	
Portland Cement	560 sacks	9 in. square brick	13,320
Sand	48 yds.	No. 1 wedge	1,080
Gravel	90 yds.	No. 1 key	2,110
		No. 2 key	1,060
Mortar		**Floor tile**	
Fireclay-grog mixture	20 tons		
Sand	3 yds.		
Cement	40 sacks	4½ x 9 x 22½ inches	850
Walls		**Center tile**	
9 in. square brick	29,300	1 set (4 pcs.) to make ring 16 in. diam.	
No. 1 arch	2,190		
No. 2 arch	3,720		
Skew brick	900		
No. 1 key	170		
No. 2 key	800	**Flue tile**	
No. 3 key	50	4½ x 9 x 34 inches	
Flashwall		**Under floor flues**	
9 in. square brick	11,400		
		9 in. square brick	28,000
Fire-box tile		No. 1 arch	3,500
9½ x 9½ x 24 inches	10 pcs.	No. 2 arch	800
Band iron			
¾ x 8 inches	231 ft.	1 x 2 x 42 inches	70 pcs.
¼ x 6 "	353 "		
¼ x 4 "	367 "		

Door frames, lugs, etc.

1x5 inches	soft steel		44 ft.
1x6 "	"	"	45 "
1x5 "	iron		34 "
1x6 "	"		20 "
1¼ "	round iron		16 "
1½ "	"	"	24 "
1¾ "	"	"	52 "

Total brick	
Squares	82,920
No. 1 arch	5,690
No. 2 "	4,520
No. 1 key	2,280
No. 2 "	1,860
No. 3 "	50
No. 1 wedge	1,080
Skew	900

Total cement	600 sacks
" sand	51 yds.
" gravel	90 yds.
" floor tile	850 pcs.
" flue tile	30 "
" firebox tile	10 "
" center tile	4 "

160	pc.	¾x1½ RH rivets
80		¾x2 "
400		¾x1 "
80		½x1 "
128		¾x1½ "
64		⅝x1½ "
40		⅝x3 "

Fire box castings—10 sets

Coil springs for—

8	in.	bands	1½ in. steel	30 ft.
6	"	"	1 " "	32 "
4	"	"	¾ " "	25 "

IV. Discussion of Design

The important features of the design are (1) the expansion joint at the base of the flashwall, (2) the supporting of the crown on the wall instead of the lining, and (3) the simplicity of the under-floor flues.

The damaging element in the firing of refractories is not the high temperature or the long periods of high fire but the sand which is used in setting. Between each course of brick or other material put in the kiln for firing a thin layer of dry white sand is sprinkled. This is usually a high grade silica sand which is used to prevent sticking together of the pieces of material. When the kiln is emptied this sand falls to the floor and fills every crack or joint between the floor tile or in the feather walls below. The floor and other brick work expand as the kiln is heated up but do not move back to the original position as the kiln is cooled and in this way a crack is formed. If this opening did not fill with sand the masonry would expand to occupy exactly the same space on the next heating up of the kiln. Because the opening does become filled, the next expansion, due to heating up, opens the crack still farther. It has been found that the greatest damage is done to the flashwall and through it to the kiln walls at the level of the floor and for a distance equal to the depth of the floor tile, or about 9 inches. The thrust and the distance traveled is so great that the kiln hobs are often pushed off the foundation. This endangers the support of the entire kiln and causes large cracks in the walls which affect the progress of the firing due to the leakage of cold air into the kiln.

The expansion joint as shown soon becomes closed as the 9-inch wall is sheared off by the thrust of the floor tile. Regular inspection as the joint narrows will dictate the time to reset the floor and rebuild the wall of the expansion ring.

It is hardly necessary to explain the advantage of supporting the crown on the outer walls instead of the lining of the kiln. The position of the lining is such that it becomes the hottest part of the kiln, and, therefore, has the greatest expansion. The tendency, if the crown rested upon the inner part of the wall, would be for the lining to expand and push up until it supported the entire crown. Since the outer parts of the wall would be cooler they would not expand upward the same distance as the lining to take their part of the load of the crown. The movement of the lining, while supporting the weight of the crown, tends to crack it, particularly over the fire-holes. On the other hand, if the crown is supported on the outer wall, leaving the lining free to expand and contract, little damage is done to the lining and it serves to protect the outer parts of the kiln walls from the high temperatures of the inside of the kiln.

The simple arrangement of the flue system is evident from the drawings. The flue to the stack is arched over in a substantial manner with a semicircular arch of four rings. This construction is amply strong to support the weight of the kiln and the load above it. The center flue is open for the entire width of the kiln. It consists of heavy walls which are backed up with grog laid in fireclay mortar. If carefully put in this backing will have very little shrinkage and the floor above will remain level indefinitely.

The midfeather flues which support the floor tile are bridged over the center flue by large fireclay tile. When the kiln bottom is to be cleaned some of the floor tile are taken up and the flue tile can be lifted out to allow a man to get into the center flue for shoveling out the sand. The floor tile used are made with a slot which is slightly larger on the lower side. This feature will allow any piece of material which passes the top side of the opening to slip on through into the midfeather without wedging in the opening.

V. Conclusions

In conclusion it may be said that the important considerations in the building of kilns are (1) simple design, and (2) careful workmanship. The simplicity of design makes for a substantial construction due to the lack of elaborate details. It also makes possible quick and complete repairs. Careful workmanship eliminates frequent overhauling and helps the kiln to operate as designed. Both, particularly in the case of a round, downdraft kiln, make for low investment, satisfactory operation, and decreased maintenance costs per ton of product which is the final standard by which all equipment must be judged.

Laclede-Christy Clay Products Co.
St. Louis, Mo.

NEW TYPE OF TUNNEL TANK REPLACES DAY TANK[1]

By Warren S. Williams

ABSTRACT

Current retail distribution methods compel the glass manufacturer to be prepared for rapid changes in style, designs, and colors. Small, flexible, producing units capable of accurate control and permitting rapid color changes or composition of glass aid in maintaining a close ratio between production and current sales. Day tanks are elastic in operation, but are not as economical or reliable as continuous tanks. A day tank was replaced with a tunnel tank (two feet wide by twenty feet long) of equivalent melting capacity per shift. Details of construction, drawing, gas consumption, filling, and operation are given. Advantages gained: dependable production with uniform color, melting conditions stabilized and assurred, producing capacity increased threefold without increasing fuel or labor costs, repair production loss cut, repair labor and material costs reduced.

Merchandizing Methods Compel Elastic Production Units

Many branches of the glass industry have recently been affected by the constantly changing market demand for colored lines, specialties, or novelties. New effects are enthusiastically received while the staple lines are largely neglected. At the same time merchandise managers are stocking the minimum quantity of any one item and attempting to force their stock carrying charges onto the manufacturer.

With the market in this condition, the manufacturer is likewise compelled to maintain a delicate balance between production and current sales and to keep his assets, organization, and equipment as flexible as possible. By controlling these factors he is prepared to lead or follow the market and can take immediate advantage of changes or developments as they arise.

The Day Tank

For many years the manufacturers of staple lines have realized additional profits from making specialties or novelties on a small scale. For this purpose day tanks are generally used for melting the glass. They meet the demand for flexible equipment and the capital investment in them is comparatively small. Changes in glass composition or color can be made overnight and the wastage of glass due to loss of color is reduced to a minimum.

The day tank has justified itself for a long time but from the standpoint of operating economy it fails to compare favorably with that of continuous tanks. Fuel consumption is disproportionate and in many cases results are erratic due to unavoidable variations in time and temperatures during the melting period.

[1] Presented at the Annual Meeting, American Ceramic Society, Detroit, Mich., Feb., 1927. (Glass Division.) Received December 6, 1926.

Disadvantages of Day Tank

These variations arise from several causes, such as varying draft conditions or pressure, variations in the heating value of the fuel, varying moisture in the batch, variations in the amounts filled, varying initial temperatures, variations in the raw materials, and in the ratios of cullet to batch. Any one of these variations may delay melting operations and cause serious loss of production. This is particularly true of those day tanks which must melt and fine the glass in twelve hours time. In these instances the margin of time is very narrow and does not permit any extensions without jeopardizing production.

Small Continuous Tank Substituted

After an extended experience with uncertain production from day tanks, the tunnel tank (2 feet wide by 20 feet long) shown in Fig. 1 was designed and built to obtain better fuel economy and more dependable melting conditions than the particular day tank which it displaced. It has been in daily operation for seven months melting opal glass for puntie gathering without showing abnormal wear. At this writing it looks good for six more months. It is flexible in that it will deliver one ton of melted glass for a day's run, or, when required, it delivers three tons of melted opal glass for twenty-four hours operation. During changing production requirements, the color is maintained by varying both the amount of batch filled and the frequency of filling.

Working Temperatures

The pyrometer at the melting end registers 2350° F, that at the cross flue, 2160°F, and the one in the working end, 1800°F. Natural gas (1100 B.t.u.) is burned with natural draft (.15 inches) in two burners; one at the melting end, and one in the working end. The chief function of the burner in the working end is to prevent surface devitrification, or scum.

Gas Consumption

Total gas consumption for the manufacturing unit composed of the tank, leer and mold oven averages 33,000 cubic feet of gas per 24 hours. This is approximately the same as consumed by the displaced day tank unit; but it could deliver only one ton while this small continuous unit delivers three tons. Enjoying a low price for natural gas, the savings in fuel values by regeneration or recuperation were disproportionate to installation and maintenance costs, so neither method was used. Gas consumption for the tank alone has never been determined. But from data secured during Sundays and holidays, when the leer was not operating, it is safe to estimate it at an average of 24,000 cubic feet per

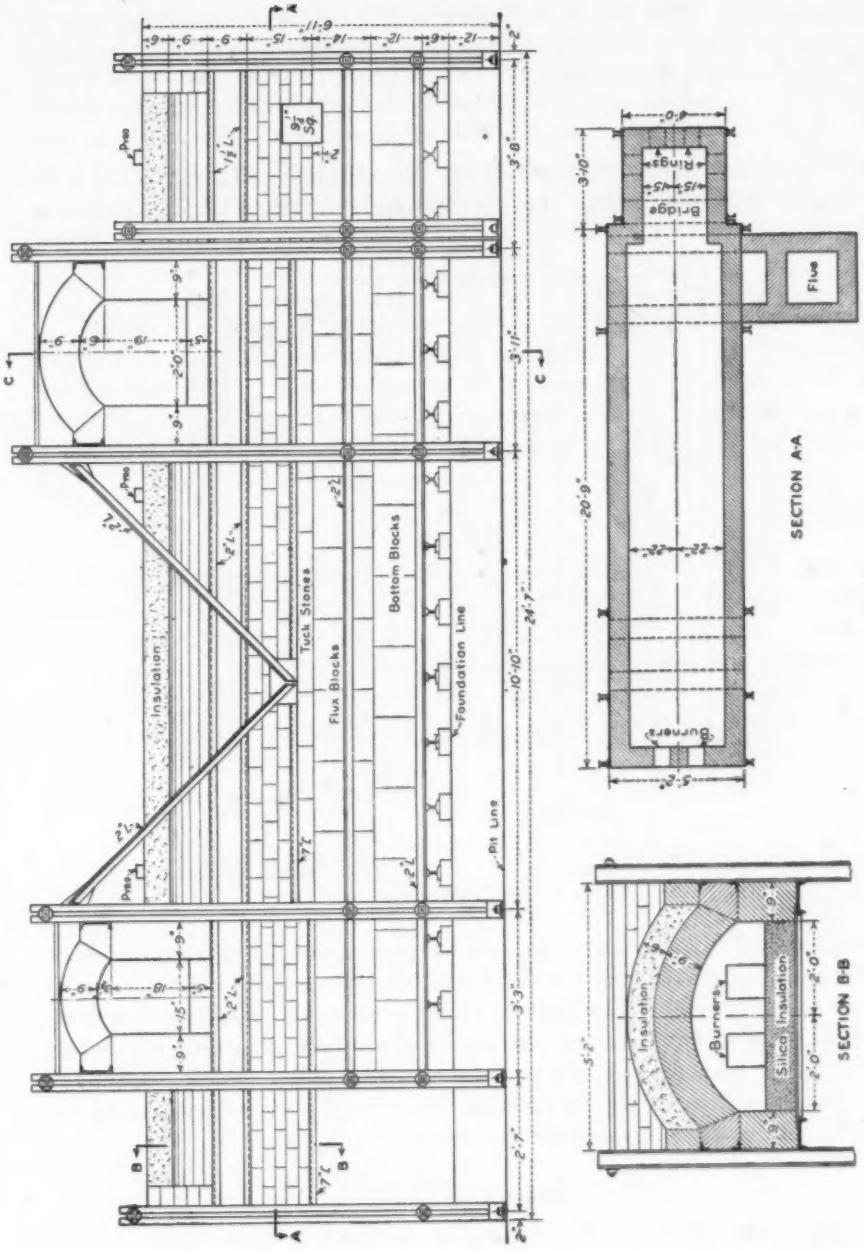
Insulation
Tuck Stones
Flue Blocks
Bottom Blocks
Foundation Line
Pit Line
Press
Rings
Bridge
Flue
Burners
SECTION A-A
Insulation
Burners
Silica Insulation
SECTION B-B

FIG. 1.

twenty-four hours. It should be borne in mind that this is purely an estimate. The leer is four feet wide by seventy feet long and is carried at 1160° F. The cap of the tank is insulated with diatomaceous earth over its whole length.

Filling

One wheel barrow (approximately 300 pounds) of batch mixed with cullet is filled every hour through a swinging door in the flue over the

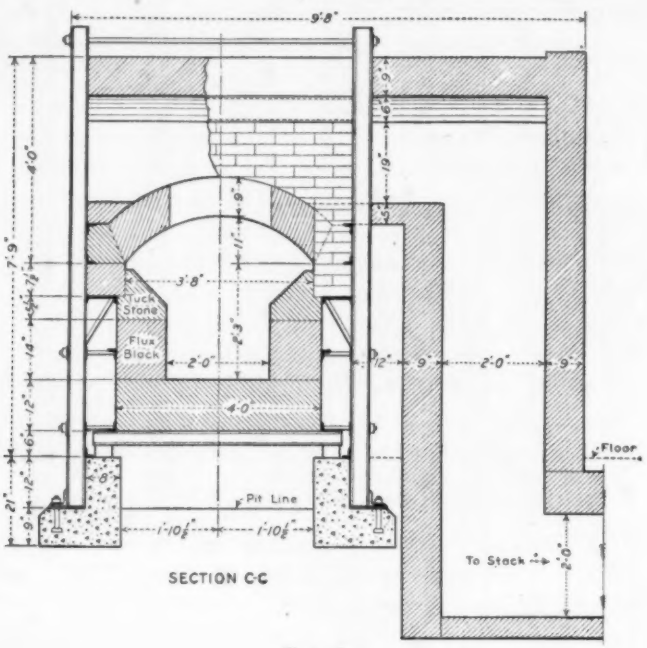

FIG. 2.

melting end. Under pressure of production the filling rate has been increased, at times, to a barrow every 45 minutes and good glass continuously obtained. The bath of metal is normally twelve inches deep, but at times it has been run at a depth of only six inches without losing the color. Sometimes it has been operated on a day tank basis, that is, worked out completely by evening, then filled and melted during the night and worked out completely during the day shift.

Reason for Design

Experience with melting opal glass in the day tank demonstrated that the glass turned flinty (lost color) at the point where the intense heat from the burner struck the pile of batch and subsequently the

surface of the metal. This fact, which is generally recognized by glass makers, led to the underlying principle of design used in the tunnel tank. It is constructed to prevent the flames from striking either the batch or metal. After leaving the short combustion chamber, the gases are drawn toward the cap by stack suction in the cross-flue on top of the cap at the working end. A baffle wall is built on the bridge block, to isolate the working chamber. The gases from the burner in the working chamber are admitted to the cross-flue through an aperture in the baffle.

Cost of Construction

Built in Los Angeles, using all locally manufactured refractories and tank block, the total cost of the tank was $1,275. The tank block and tuck stones can be readily replaced without disturbing the cap which is good for several years service. This feature means a large saving in repair materials and time in comparison with the day tank, which had to be totally demolished to replace corroded block.

Summary

The results secured by replacing a day tank with a tunnel tank of equivalent producing capacity per shift are (1) dependable production and uniform color, (2) melting conditions stabilized and assured, (3) producing capacity tripled, (4) fuel consumption not increased, (5) operating labor costs not increased, (6) repair time cut, production schedules quickly regained, (7) repair materials cost reduced, (8) repair labor cost reduced.

815 East Harvard Street,
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AN ELECTRIC TUNNEL KILN[1]

By A. S. W. Odelberg

ABSTRACT

A diagrammatic description of kilns and resistors is given for electric tunnel kilns suitable for small ware. Experience, cost data, and results of biscuit, glost, and decorating are recited. Data are given showing that with high power cost the net cost per cup or plate is less in an electric tunnel kiln than in periodic kilns.

The paper on "The Harper Electric Kiln" by Francis A. J. FitzGerald is very interesting.[2] Glost firing of china on a commercial scale in an electric tunnel kiln has been done in Stockholm for the last two years.

The experimental kiln has been made possible by the research carried out at the Works of the Morgan Crucible Company by C. W. Speirs.

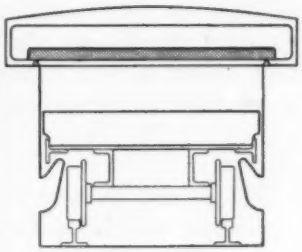

Fig. 1.

The Resistors

The Morgan Crucible Company Limited has produced and patented a ceramic resistor which is capable of attaining temperatures up to 1400°C, and will operate continuously at this temperature for periods of from two to three months.

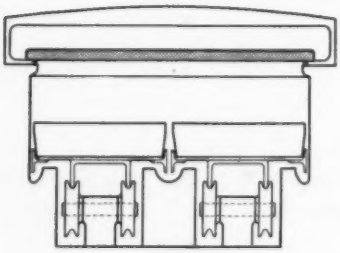

Fig. 2.

These resistors can be made in any desired shape, but for pottery kilns they are made in flat sheets up to 7 feet long by 2 feet wide, and can be mounted either horizontally forming the roof, or vertically forming the sides, of a tunnel kiln. Sketches of the resistors used are shown.

For many years we considered glost firing cups and plates and other ware by means of electricity, but had always been unable to obtain a suitable resistor for this purpose. During the ceramic tour in France 1921, I learned from Mr. Speirs that his firm had been experimenting in the production of a resistor for high tem-

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[1] Presented at the Annual Meeting, American Ceramic Society, Detroit, Mich., Feb., 1927. (White Wares Division.) Received January 10, 1927.

[2] *Jour. Amer. Ceram. Soc.*, 9 [11], 766 (1926).

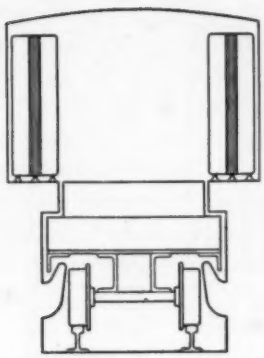

FIG. 3.

peratures and during the ceramic tour in Sweden in 1922, I learned that one of my countrymen was melting metal in a crucible heated by electricity, and the question of supplying a resistor for a pottery kiln was then considered.

I paid a special visit to England to see the work that was being done by the Morgan Crucible Company in this line, and saw in operation a small furnace about 15 feet long, 2 feet deep and 2 feet wide, heated to a temperature of 1250°C by means of a resistor 6 feet long, which formed the roof of the center part of this muffle.

With the assistance of Mr. Speirs, designs for a trial kiln for glost firing of cups were prepared, but it was not until January, 1924, that the Morgan Crucible Company was in a position to quote me for a suitable plant. Unavoidable delays resulted in the resistors being delivered at the end of 1924.

For the original trials the Morgan Crucible Company lent a special 36 kw transformer to obtain the variation in temperatures required for the trials.

Due to strikes in Sweden the trial kiln was not started until the spring of 1925.

The Kiln

The original experiments were made with a kiln only 20 feet long having a hot zone of 6 feet. This proved so satisfactory that a kiln which is now known as No. 1 kiln was built and started to work in July, 1925. It is about 55 feet long with

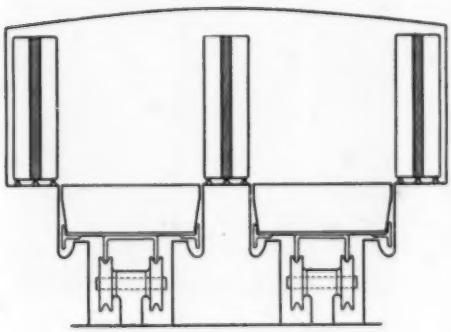

FIG. 4.

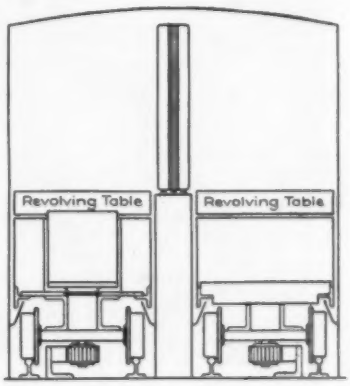

FIG. 5.

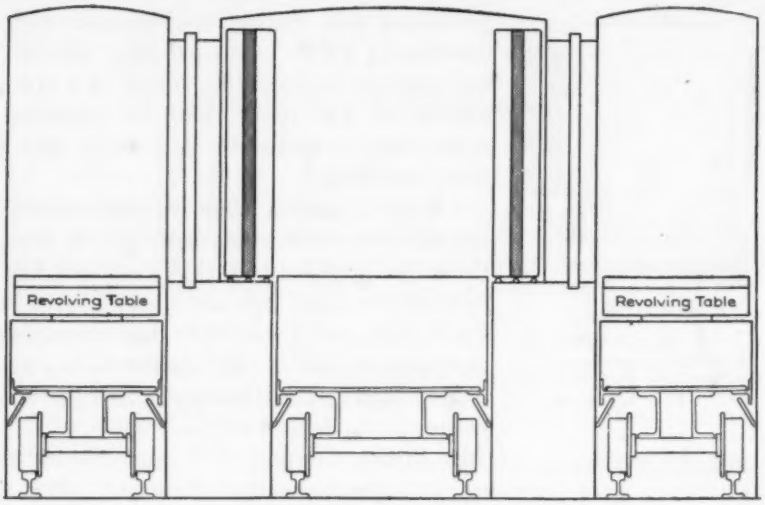

FIG. 6.

30 trucks approximately 21 by 17½ inches, each truck holding about 2½ dozen cups. This kiln has been in constant operation since that time.

On the average six trucks are fed in per hour, one every 10 minutes producing over 2500 dozen cups per week, the total loading of the kiln being in the neighborhood of 32 kw and the power consumed being about 2 units per dozen cups.

Early this year C. W. Speirs arranged to put two resistors instead of one into this kiln. This more than doubled the length of the hot zone and more than doubled the output of the kiln per hour. With

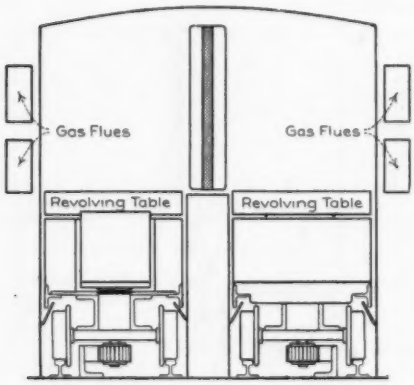

FIG. 7.

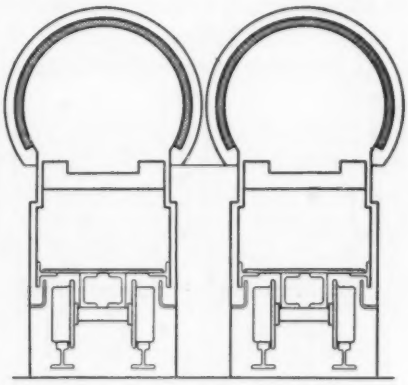

FIG. 8.

two resistors 12 trucks were fed in per hour or one truck every 5 minutes, giving an output of 5,000 dozen cups per week, the total loading of the kiln being about 60 kw.

Special trial runs were made in which as many as 15 trucks per hour were fed into the kiln, or one every four minutes; the loading was increased to about 65 kw, production being at the rate of over 6,000 dozen cups per week.

FIG. 9.

This greatly improved the efficiency of the kiln, the power taken being reduced to about 1.7 units per dozen. Due to mechanical reasons it was not possible to keep up this rate of feed, but a steady output of 12 trucks per hour has since been maintained with two resistors.

In autumn of 1926, a new kiln was designed in which two lines of trucks working in the same kiln but in opposite directions, was put into operation. These trucks give a surface of about 5 by 1 feet, the longer truck greatly reducing the cost of working the kiln as fewer trucks per hour are necessary for the same output. This kiln is known as No. 2 kiln and is fitted at present with two resistors. Arrangements are made to fit three resistors if necessary.

The kiln has an overall length of about 60 feet. The figures give a

FIG. 10.—Taking out truck with fired ware, Kiln 1.

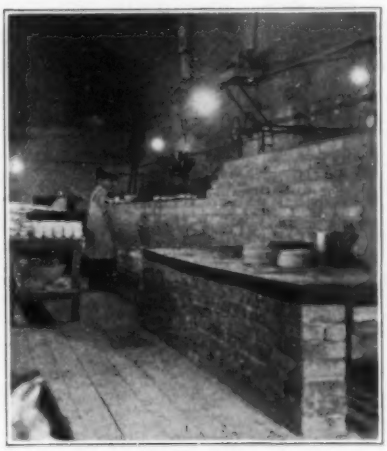

FIG. 11.—General view of Kiln 2.

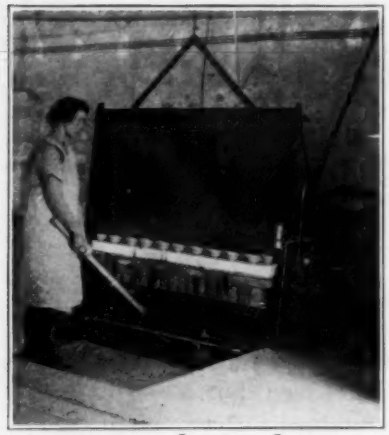

FIG. 12.—Taking out truck with fired ware, Kiln 2.

diagrammatic view of the cross-section of the kiln.

No. 2 kiln has many detail improvements and it has been found possible to glost fire cups at the rate of one dozen per minute using one unit of electricity.

The cost of resistors has been found in practice to be less than the cost for saggers which were necessary in the periodic coal-fired kiln, but which are unnecessary in the electrical kiln.

The wages are obviously much lower in the electric kiln than in the coal-fired kiln. I have found however that the important feature of the kiln is that the ware is of a uniform type and little, if any, rejections are caused by the kiln; in fact after many months experience it is safe to take the rejections at under one per cent. The saving under this head over the cost of rejections from a coal-fired kiln, more than pays for the running costs of an electrical kiln.

I am now erecting an electrical kiln for the glost firing of plates and other articles. The estimated savings from the costs of this kiln show even greater savings than with the kiln for cups as each truck carries a greater weight of ware with plates than with cups.

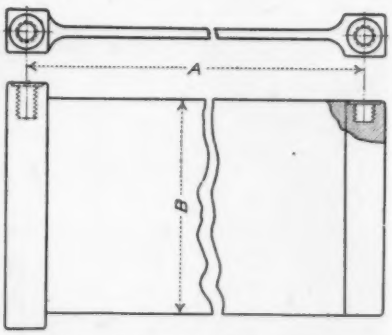

FIG. 13.—Morgan's high temperature element (verticle pattern).

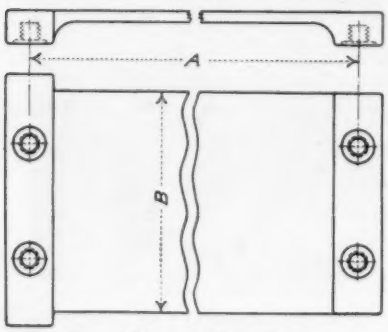

FIG. 14.—Morgan's high temperature resistor element (horizontal pattern).

We have carried out experiments both at enameling temperatures in the neighborhood of 800°C, and biscuit firing temperatures in the neighborhood of 1260°C with No. 1 kiln, and the results of these tests indicate that there will be no difficulty in firing both the enamel and the biscuit ware on a commercial scale in an electrically fired kiln.

TABLE I

Actual Readings from Log Sheet. No. 1 Kiln.

1925		Number of Trucks Fed into Kiln	Dozens Cups	Elect. Units	Temperature °C
Sept. 30	Started up				
	5:20 P.M.–10 P.M.			125	500
	10 P.M.– 6 A.M.			252	940
	6 A.M.– 2 P.M.			307	1070
Oct. 1	2 P.M.–10 P.M.	37	92.5	310	1050
	10 " – 6 A.M.	48	120	308	1040
	6 A.M.– 2 P.M.	47	117.5	296	1080
" 2	2 P.M.–10 P.M.	48	120	304	1070
	10 " – 6 A.M.	"	"	295	1030
	6 A.M.– 2 P.M.	"	"	309	1100
" 3	2 P.M.–10 "	"	"	294	1100
	10 " – 6 A.M.	"	"	308	1070
	6 A.M.– 2 P.M.	"	"	301	1100
" 4	2 P.M.–10 "	"	"	300	1100
	10 " – 6 A.M.	"	"	291	1100
	6 A.M.– 2 P.M.	"	"	300	1140
" 5	2 P.M.–10 "	"	"	296	1100
	10 " – 6 A.M.	"	"	300	1080
	6 A.M.– 2 P.M.	"	"	299	1090
" 6	2 P.M.–10 "	"	"	295	1100
	10 " – 6 A.M.	"	"	290	1100
	6 A.M.– 2 P.M.	"	"	306	1100
" 7	2 P.M.–10 "	"	"	301	1100
	10 " – 6 A.M.	"	"	289	1080
	6 A.M.– 2 P.M.	"	"	298	1080
" 8	2 P.M.–10 "	"	"	297	1090
	10 " – 6 A.M.	"	"	286	1080
	6 A.M.– 2 P.M.	"	"	313	1100
" 9	2 P.M.–10 "	"	"	292	1100
	10 " – 6 A.M.	"	"	289	1070
	6 A.M.– 2 P.M.	"	"	301	1090
" 10	2 P.M.–10 "	"	"	304	1090
	10 " – 6 A.M.	"	"	296	1080
	6 A.M.– 2 P.M.	"	"	292	1100
" 11	2 P.M.–10 "	"	"	305	1080
	10 " – 6 A.M.	"	"	287	1080
	6 A.M.– 2 P.M.	"	"	299	1080
" 12	2 P.M.–10 "	"	"	295	1100
	10 " – 6 A.M.	"	"	289	1070
	6 A.M.– 2 P.M.	"	"	293	1100
" 13	2 P.M.–10 "	"	"	290	1080
	10 " – 6 A.M.	"	"	292	1080
	6 A.M.– 2 P.M.	"	"	285	1070
" 14	2 P.M.*–10 "	43	107.5	300	1100
	10 " – 6 A.M.	48	120	289	1080
Oct. 15	6 A.M.– 2 P.M.	48	120	283	1
	2 P.M.–10 "	"	"	309	1
	10 " – 6 A.M.	"	"	292	1
	6 A.M.– 2 P.M.	"	"	289	1
" 16	2 P.M.–10 "	"	"	289	1
	10 " – 6 A.M.	"	"	286	1
	6 A.M.– 2 P.M.	"	"	290	1
" 17	2 P.M.–10 "	"	"	289	1
	10 " – 6 A.M.	"	"	296	1
	6 A.M.– 2 P.M.	"	"	307	1
" 18	2 P.M.–10 "	"	"	291	1
	10 " – 6 A.M.	"	"	293	1
	6 A.M.– 2 P.M.	"	"	291	1
" 19	2 P.M.–10 "	"	"	298	1
	10 " – 6 A.M.	"	"	292	1
	6 A.M.– 2 P.M.	"	"	296	1
" 20	2 P.M.–10 "	"	"	293	1
	10 " – 6 A.M.	"	"	301	1
	6 A.M.– 2 P.M.	"	"	292	1
" 21	2 P.M.–10 "	"	"	288	1
	10 " – 6 A.M.	"	"	295	1
	6 A.M.– 2 P.M.	"	"	291	1
" 22	2 P.M.–10 "	"	"	284	1
	10 " – 6 A.M.	"	"	300	1
	6 A.M.– 2 P.M.	"	"	283	1
" 23	2 P.M.–10 "	"	"	290	1
	10 " – 6 A.M.	"	"	292	1
	6 A.M.– 2 P.M.	"	"	283	1
" 24	2 P.M.–10 "	"	"	294	1
	10 " – 6 A.M.	"	"	311	1
	6 A.M.– 2 P.M.	"	"	285	1
" 25	2 P.M.–10 "	"	"	292	1
	10 " – 6 A.M.	"	"	280	1
	6 A.M.– 2 P.M.	"	"	285	1
" 26	2 P.M.–10 "	"	"	294	1
	10 " – 6 A.M.	"	"	285	1
	6 A.M.– 2 P.M.	"	"	288	1
" 27	2 P.M.–10 "	"	"	290	1
	10 " – 6 A.M.	"	"	289	1
	6 A.M.– 2 P.M.	"	"	292	1
" 28	2 P.M.–10 "	"	"	297	1
	10 " – 6 A.M.	"	"	289	1
	6 A.M.– 2 P.M.	"	"	292	1
" 29	2 P.M.–10 "	"	"	295	1
	10 " – 6 A.M.	"	"	291	1

* Stopped 1 hour

BLE I

Log Sheet. No. 1 Kiln.

er cks to	Dozens Cups	Elect. Units	Temperature °C	1925			Number of Trucks Fed into Kiln	Dozens Cups	Elect. Units	Temperature °C
8	120	283	1070			6 A.M.– 2 P.M.	48	120	291	1060
	"	309	1050	Oct.	30	2 P.M.–10 "	"	"	296	1070
	"	292	1080			10 " – 6 A.M.	"	"	289	1070
	"	289	1080			6 A.M.– 2 P.M.	47	117.5	288	1115
	"	289	1060	"	31	2 P.M.–10 "	48	120	294	1115
	"	286	1070			10 " – 6 A.M.	"	"	279	1080
	"	290	1070			6 A.M.– 2 P.M.	"	"	296	1080
	"	289	1060	Nov.	1	2 P.M.–10 "	"	"	287	1080
	"	296	1070			10 " – 6 A.M.	"	"	280	1070
	"	307	1070			6 A.M.– 2 P.M.	"	"	293	1080
	"	291	1060	"	2	2 P.M.–10 "	"	"	285	1080
	"	293	1060			10 " – 6 A.M.	"	"	286	1080
	"	291	1070			6 A.M.– 2 P.M.	"	"	285	1080
	"	298	1060	"	3	2 P.M.–10 "	"	"	294	1130
	"	292	1060			10 " – 6 A.M.	"	"	283	1070
	"	296	1070			6 A.M.– 2 P.M.	"	"	283	1070
	"	293	1060	"	4	2 P.M.–10 "	"	"	283	1070
	"	301	1060			10 " – 6 A.M.	"	"	281	1070
	"	292	1060			6 A.M.– 2 P.M.	"	"	275	1060
	"	288	1070	"	5	2 P.M.–10 "	"	"	289	1070
	"	295	1060			10 " – 6 A.M.	"	"	285	1070
	"	291	1070			6 A.M.– 2 P.M.	49	122.5	295	1070
	"	284	1060	"	6	2 P.M.–10 "	48	120	286	1100
	"	300	1060			10 " – 6 A.M.	"	"	281	1070
	"	283	1060			6 A.M.– 2 P.M.	"	"	285	1080
	"	290	1060	"	7	2 P.M.–10 "	"	"	284	1060
	"	292	1060			10 " – 6 A.M.	"	"	287	1060
	"	283	1070			6 A.M.– 2 P.M.	"	"	288	1080
	"	294	1060	"	8	2 P.M.–10 "	"	"	285	1070
	"	311	1060			10 " – 6 A.M.	"	"	283	1060
	"	285	1070			6 A.M.– 2 P.M.	"	"	285	1060
	"	292	1060	"	9	2 P.M.–10 "	"	"	285	1070
	"	280	1050			10 " – 6 A.M.	"	"	281	1060
	"	285	1050			6 A.M.– 2 P.M.	"	"	299	1070
	"	294	1050	"	10	2 P.M.–10 "	"	"	292	1080
	"	285	1050			10 " – 6 A.M.	"	"	291	1080
	"	288	1050			6 A.M.– 2 P.M.	"	"	301	1080
	"	290	1050	"	11	2 P.M.–10 "	"	"	283	1090
	"	289	1050			10 " – 6 A.M.	"	"	289	1100
	"	292	1050			6 A.M.–7.35 A.M.			52	1060
	"	297	1060	"	12	* Resistor failed.				
	"	289	1050							
	"	292	1060	Total number of cups 15,120 doz.						
	"	295	1070	" " units 36,288						
	"	291	1060	=2.4 units per doz. cups.						

Tables I, II, III, IV, and V give particulars of kilns Nos. 1 and 2 and Figs. 1 to 9 give diagrammatic cross-sections of various arrangements for kilns operating with resistors.

Figures 1 and 2 are cross-sections of the kilns in operation in these Works.

Figures 3, 4, and 5 show a kiln for firing plates and other general ware.

Figure 6 shows a special application of these resistors in which the central tunnel is operated at a higher temperature than the outside, *i. e.*, the inside tunnel doing biscuiting ware and the outside glost, or the inside tunnel doing glost ware and the outside tunnels enameling.

Figure 7 shows the method of reducing the power costs by balancing the radiation losses by using a cheaper form of heat such as producer gas or oil in flues in the walls of the kiln.

Figure 8 shows a special shape of resistor particularly suitable for high temperatures in the neighborhood of 1400°C.

Figure 9 is a resistor for annealing metal wire or balls and is not for any particular ceramic purpose.

DIRECTOR OF GUSTAVSBERG CHINA WORKS
STOCKHOLM, SWEDEN

TABLE II

No. 1 Kiln. (Experimental nonregenerative)
One line of trucks (Length 55 ft., approximately 16.75 m)
Each truck 21¼ x 17½ in. (555 mm x 445 mm) (2½ doz. cups per truck)
Shift = 8 hrs. Kiln working continuously = 21 shifts per week.

Number of trucks per hour	Trucks fed at intervals of (in mins.)	Cups per hour (dozens)	Trucks per shift	Cups per shift (dozens)	Cups per week (dozens)	Rate of travel of truck (in inches per min.)	Rate of travel of truck (in M/M per min.)	Time cups are in kiln hours	Time cups are in kiln mins.	With labor cost per hour at 2 shillings cost per doz. cups (in pence)
5	12	12.5	40	100	2,100	1.82	46	6	2	1.92
6	10	15	48	120	2,520	2.18	55.5	5	3	1.6
7	8.6	17.5	56	140	2,940	2.54	63.5	4	20	1.37
8	7.5	20	64	160	3,360	2.92	74	3	46	1.2
9	6.7	22.5	72	180	3,780	3.28	83.3	3	21	1.07
10	6	25	80	200	4,200	3.64	92	3	1	.96
11	5.45	27.5	88	220	4,620	4	101.5	2	45	.875
12	5	30	96	240	5,040	4.37	111	2	31	.8
13	4.6	32.5	104	260	5,460	4.75	120.6	2	19	.74
14	4.3	35	112	280	5,880	5.1	130	2	9	.68
15	4	37.5	120	300	6,300	5.47	139	2	1	.64
16	3.75	40	128	320	6,720	5.83	148	1	53	.6

Note: Tables II and IV give particulars of an experimental nonregenerative kiln which has very poor heat insulation.

Tables III and V give particulars of a regenerative kiln well heat insulated.

The power required to fire 1 dozen average cups may vary between 1 and 2.5 units (Articles requiring more power will reduce the output accordingly).

The power depends on the size and weight of the article and the temperature required. The capacity of the kilns is varied by the number of resistors employed.

Cups have been satisfactorily fired that were only in the hot zone 26 minutes. It will be noted that the maximum rate of feed in No. 2 kiln allows 30–36 minutes in Hot Zone with 3 resistors.

If an output of above 63 dozen per hour is required, 3 resistors are recommended. If the articles to be fired require 2 units per dozen or more, then the maximum output of the kiln will not exceed *72 dozen* per hour.

TABLE III

No. 2 Kiln (regenerative)

Two lines of trucks (length 59 ft. 18 m)
Each truck 59.05 in. x 11.25 in. (1.5 m x 285 mm) (4½ doz.) cups per truck.
Shift = 8 hrs. Kiln working continuously = 21 shifts per week.

Numbers of trucks per hour	Trucks fed in each end at intervals of (in mins.)	Total trucks per hour	Cups per hour (in doz.)	Trucks per shift	Cups per shift (in dozens)	Cups per week (in doz.)	Rate of Travel of Truck		Time Cups are in Kiln		With labour cost per hour at 2 shillings, cost per dozen cups (in pence)
							inches	mm	hours	mins.	
5	12	10	45	80	360	7560	4.9	124	2	25	.54
6	10	12	54	96	432	9072	5.9	150	2		.45
7	8.6	14	63	112	504	10584	6.8	173	1	44	.39
8	7.5	16	72	128	576	12096	7.9	200	1	30	.34
9	6.7	18	81	144	648	13608	8.8	223	1	20	.3
10	6	20	90	160	720	15120	9.8	249	1	12.5	.27

NOTE: Total time in kiln to allow sample cooling can be given by increasing the length of kiln.

TABLE IV

No. 1 Kiln (Experimental nonregenerative)

One line of trucks
One resistor 6 ft. (1.83 m) = hot zone, 6 ft. (1.83 m).
Two resistors 6 ft. + 1 ft. space (1.83 m + 305 mm) = hot zone 13 ft. (3.96 m).

Number of trucks per hour	Cups per hour (in dozens)	Time that truck is in hot zone (in minutes)		Total kw loading for one resistor, at (units per dozen cups)				2 Resistors Loading per resistor at (units per dozen cups)			
		1 resistor	2 resistors	1	1.5	2	2.5	1	1.5	2	2.5
5	12.5	39.5	86	12.5	18.75	25	31.25	6.25	9.3	12.5	15.6
6	15	32	71.5	15	22.5	30	37.5	7.5	11.2	15	18.7
7	17.5	28.4	61.5	17.5	26.25	35	43.75	8.7	13.1	17.5	21.8
8	20	24.6	53.5	20	30	40	50	10	15	20	25
9	22.5	22	47.5	22.5	33.75	45	56.25	11.2	16.8	22.5	28.1
10	25	19.8	43	25	37.5	50	62.5	12.5	18.7	25	31.2
11	27.5	18	39	27.5	41.25	55	68.75	13.7	20.6	27.5	34.3
12	30	16.5	35.7	30	45	60	75	15	22.5	30	37.5
13	32.5	15.2	32.8	32.5	48.75	65	81.25	16.2	24.3	32.5	40.6
14	35	14.1	30.6	35	52.5	70	87.5	17.5	26.2	35	43.7
15	37.5	13.2	28.6	37.5	56.25	75	93.75	18.7	28.1	37.5	46.8
16	40	12.3	26.8	40	60	80	100	20	30	40	50

Loading on resistor not to exceed 40 kw.

Discussion[1]

BY CHARLES W. SPEIRS

The important difference between this kiln and other electric kilns working at high temperatures is the type of resistor employed, which enables the heat to be brought as near as possible to the ware to be

[1] Received January 28, 1927.

TABLE V

No. 2 Kiln (regenerative)

Hot zone { Two lines of trucks
2 resistors, 7 ft. (2.13 m) each + 2 ft. (610 mm) space between each = approx. 16 ft. (4.88 m).
3 resistors, 7 ft. (2.13 m) each + 2 ft. (610 mm) space between each = approx. 25 ft. (7.62 m).

Number of trucks per hour	Cups per hour (in dozens)	Time that truck is in hot zone (in mins.) 2 Resistors	3 Resistors	Total kw Loading and for one resistor at (units per dozen cups) 1	1.25	1.5	2	2 Resistors loading per resistor at (units per dozen cups) 1	1.25	1.5	2	3 Resistors loading per resistor at (units per dozen cups) 1	1.25	1.5	2
5	45	39.2	61.2	45	56.25	67.5	90	22.5	28.1	33.75	45	15	18.7	22.5	30
6	54	32.6	51	54	67.5	81	108	27	33.75	40.5	54	18	22.5	27	36
7	63	28.2	44	63	78.75	94.5	126	31.5	39.4	47.25	63	21	26.2	31.5	42
8	72	24.3	38	72	90	108	144	36	45	54	72	24	30	36	48
9	81	21.8	34	81	101.25	121.5	162	40.5	50.6	60.75	81	27	33.75	40.5	54
10	90	19.6	30.6	90	112.5	135	180	45	56.25	67.5	90	30	37.5	45	60

Loading on Resistor not to Exceed 50 K.W.

heated and exactly in the position required, without any form of covering or support between the heat and the ware.

The ware can go quickly through the kiln because the truck is narrow and the ware is not stacked high. Every piece of ware on each truck is fired to the same time-temperature curve. Careful tests on any existing tunnel kiln show that both the time-temperature curve and the atmospheric conditions of different parts on any one truck are very different. The rate of travel must be slow to enable the temperature to ultimately even out more or less through the ware on the one truck. I believe that the highest efficiency cannot be obtained until the time temperature curve and atmospheric conditions of all parts of the ware on a truck are the same. The small kiln will produce the same total ware as a kiln four times its cross-section because the trucks travel four times as quickly. All ware will be of the same standard and the advantages of the smaller kiln are too obvious to enumerate.

Capital Cost A rough comparison of the cost of the kiln is obtained from the fact that in England an electric kiln, complete with all trucks and electrical transformers will cost less and have a larger output than the round, periodic, coal-fired kiln 20 feet diameter and 20 feet high inside dimensions. From rough estimates obtained in this country a kiln (No. 2) that will glost fire 10,000 dozen average cups or the equivalent per week will cost, with two horizontal resistors and two transformers, about $12,000. There is very little brick work in the kiln. The kiln as No. 4, with three vertical resistors, will cost about the same sum and produce from 4,000 to 5,000 dozen 10½-inch plates per week. By doubling the length of the hot zone with extra resistors, the capacity of both kilns can be increased at little extra cost.

NOTE.—A saving of only 3 cents per dozen cups, or 6 cents per dozen plates will more than pay for the kiln in the first year.

Power Both the above kilns will take from 60 to 80 kilowatts, according to the type of the ware and glaze employed for the outputs given. That is to say, from one to 1.5 kw. hrs. per dozen cups and from 2 to 3 kw. hrs. per dozen plates.

Maintenance With the exception of the resistors the maintenance is negligible. The resistor is the point of highest temperature in the kiln and the structure is not subjected to excessive temperatures as in the case of all other kilns.

Two resistors for No. 2 kiln, 7 ft. by 2 ft. cost approximately $150 each f.o.b. England.

Three resistors for No. 4 kiln, 7 ft. by 1 ft. cost approximately $100 each f.o.b. England. The cost of the resistors per dozen articles

fired will be found in practice to be less than the present cost for saggers. The resistors will require replacing every two or three months. The maximum time taken to replace resistors from stop to start is 48 hours.

Erection Due to the short length and light weight the kiln can be erected in almost any position. The most suitable place is on a light, ferro-concrete platform, about 6 or 7 ft. above the shop level, so as not to interfere with any of the shop gangways. As the kiln is so small and cheap, it has the great advantage that several units can be built each in the best position to suit the layout of the plant.

The kiln is particularly suitable for small works that have not previously had the opportunity of operating tunnel kilns.

Operation The kiln can be operated by girl labor during the day time. The same kiln can be used for glost and enameled firing and in special circumstances for biscuit. The change from one to the other can be made at short notice.

My experience in the firing of pottery on a commercial scale with the electric kiln has been confined to glost firing, but the large number of tests made with enamel and biscuit confirmed by my experience with firing articles and materials of all kinds, leads me to the conclusion that the kiln can be used economically for all purposes.

Ask any of your friends who now make steel or melt brass electrically if they would go back to the use of any other source of heat.

There are so many detail advantages with electric firing that they can only be realized by actual experience.

A feature that alone justifies the erection of one kiln in every large works, is its value for test purposes. Hardly a day passes without some department wanting to test a new body, glaze or color. To obtain results in the afternoon from test pieces placed in the kiln in the morning is of great value. It is difficult to translate this saving into cash but it is high. The finest adjustments can be made in temperature so that the most perfect conditions can be obtained to suit all cases. There are no gases and the atmosphere can be made oxidizing or reducing as required. Several plants have just been completed in England and I shall be glad to give my fellow-members the results at an early date.

DRAFT COMPARISON OF CEMENT AND CLAY GAS FLUES[1]

By A. Lee Bennett

ABSTRACT

The purpose of this investigation was to obtain comparison of cement and clay gas flues.

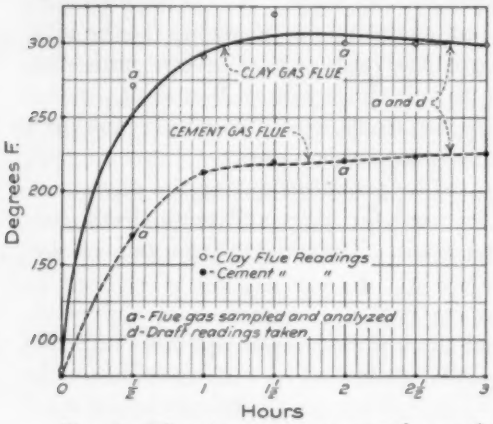

FIG. 1.—Time-temperature curves for gas flue tests. (Temperatures at bottom of flues plotted against time.) Part A.

A tested gas meter was introduced into each circuit. The gas from the main line was split at a tee and then passed through the meters (which were identical in size and construction) to the heating appliances. The length of all connecting pipes in each circuit was made the same, so as to eliminate any unequal friction in them.

The Testing[2]

Part A With the equipment arranged as described and with tested thermometers in place in the gas

Procedure

The equipment consisted of two vertical gas flues twenty feet in height. The clay flue was approximately 2 x 6¼ inches inside, 12.5 square inches, and the cement gas flue was very close to 2 x 6½ inches inside dimensions, or 13.0 square inches in area. At the bottom of each stack a standard four-section sheet-iron gas heater was connected. The gas heaters were identical in size and construction.

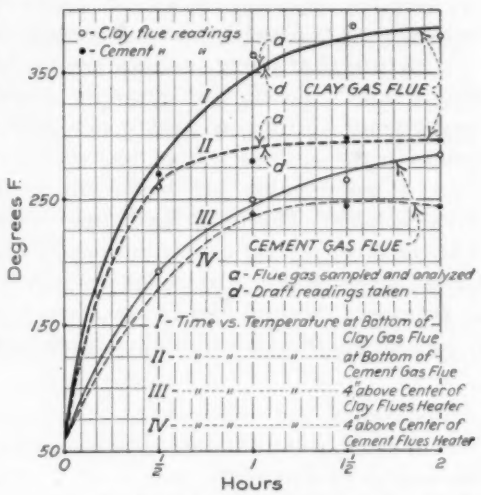

FIG. 2.—Time-temperature curves for gas flue test. Part B.

[1] Presented at the Annual Meeting, American Ceramic Society, Detroit, Mich., Feb., 1927. (Heavy Clay Products Division.)

[2] Similar tests and observations were made on two previous occasions, the same comparative results being obtained as reported.

flues, the heaters were lighted and adjusted so as to burn a "medium" amount of gas at as nearly identical rates as possible. The flue temperatures, gas volumes, draft, and flue gas composition were then observed as follows:

RESULTS

Gas Analyses — Total Gas Consumed

Start of test at 1:30 P.M. — No. 1 3:30 P.M. — Clay flue 29¾ cu. ft.
No. 2 4:15 P.M. — Cement flue 29⅛ cu. ft.

Reading	Time (P.M.)	Clay Flue Top °F	Cement Flue Top °F	Clay Flue Bottom °F	Cement Flue Bottom °F
1	1:30	80	83	78	76
2	2:00	99	85	270	170
3	2:30	109	91	290	212
4	3:00	117	94	320	220
5	3:30	117	96	300	221
6	4:00	121	96	300	224
7	4:30	120	96	298	226

RESULTS OF GAS ANALYSES

	No. 1 (at 3:30 P.M.) Clay Flue	No. 1 (at 3:30 P.M.) Cement Flue	No. 2 (at 4:15 P.M.) Clay Flue	No. 2 (at 4:15 P.M.) Cement Flue	Draft Readings* (by anemometer) at 4:15 P.M. Clay Flue f/m	Draft Readings* (by anemometer) at 4:15 P.M. Cement Flue f/m
Carbon Dioxide	1.7%	2.4%	1.4%	2.6%	(1) 298	211
Oxygen	18.3	18.0	18.4	17.4	(2) 299	195
Carbon Monoxide	0.0	0.1	0.0	0.2	(3) 285	189
					(4) 320	211
					Av. 300+	199+

Note: The No. 2 gas analyses samples and the draft readings were taken as near simultaneously as possible. Each gas analysis reading was checked at least twice (three identical readings) before the result was accepted.

* The relative drafts in the flues were determined by placing an anemometer at the top of each flue. These readings were standardized by placing a cardboard with a circular opening slightly less than that of the anemometer, over the flues. Thus, the size of the draft opening, as well as the position of the anemometer, were identical throughout the tests.

Part B The stacks and appliances used in Part A were allowed to cool down to room temperature (overnight). Then, without changing the setup of the apparatus, except to adjust the heaters to a rapid rate of gas combustion, the burners were lighted and the following observations made:

RESULTS OF GAS ANELYSES

Gas Analysis — Total Gas Consumed

Started at 9:30 A.M. — Clay Flue 48½ cu. ft.
Finished at 11:30 A.M. — 10:35 A.M. — Cement Flue 48 cu. ft.

Reading	Time (A.M.)	Clay Flue Top °F	Cement Flue Top °F	Clay Flue Bottom °F	Cement Flue Bottom °F	Temp. 4 inches above Center of Heaters Clay °F	Temp. 4 inches above Center of Heaters Cement °F	Total Gas Consumed Clay Heater cu. ft.	Total Gas Consumed Cement Heater cu. ft.
1	9:30	59	60	60	59	60	60	0.0	0.0
2	10:00	111	79	260	270	192	252†	12.5	12.0
3	10:30	125	93	364	280	250	238	23.5	23.0
4	11:00	136	100	387	298	265	245	36.0	36.25
5	11:30	138	102	378	296	286	244	48.3	48.0

† This reading should be thrown out due to direct flames blowing out from the heater near the suspended thermometer. To prevent this action the small doors in the heaters were left open throughout the remainder of the test. Otherwise, the flames continually "rolled" out of the cement flues heater at the rapid gas consumption to which both heaters were adjusted.

RESULTS OF GAS ANALYSES

	Samples taken at 10:35 A.M.		Draft Readings (by anemometer at 10:40 A.M.	
	Clay Flue %	Cement Flue %	Clay Flue f/m	Cement Flue f/m
Carbon Dioxide	2.9	2.1	(1) 284	232
Oxygen	16.1	16.3	(2) 293	223
Carbon Monoxide	0.0	0.8	Av. 289	228

Note: As in Part A, each gas analysis reading was checked at least twice (three identical readings) before the result was accepted.

A Hayes type of modified Orsat apparatus, especially designed for the determination of carbon dioxide, oxygen and carbon monoxide in flue gases was used. The apparatus was checked for precision both before and after the test to further insure the accuracy of the data.

Discussion

The data obtained in both parts of this test demonstrate that the clay gas flue will, with equal rates of gas consumption in identical heaters, become warmer from top to bottom than a cement gas flue of equal size. As is always the case, the warmer flue was consistently found to produce a greater draft. In this particular test, the data shows from about 21% (Part B) to 34% (Part A) greater draft in the clay flue on a basis of the clay flue draft as 100%. If the cement flue draft were taken as a basis, the clay flue would have from 26 to 50% more draft. Also, the largest proportion of draft in the clay, as compared with the cement gas flue, was obtained with an average rate of gas combustion in the heating appliances.

The composition of the gases in the cement and clay gas flues reveals the effect of this better draft in the clay flue on gas combustion in the appliances. Every sample of gas taken from the cement flue contained definite quantities of carbon monoxide, as high as 0.8% being present in the sample taken during the second part of this test. This fact clearly demonstrates the improper combustion of gas in the heater vented by the cement gas flue.

In the second part of the test (Part B) the higher percentage of carbon dioxide in the clay flue gases coupled with the fact that no carbon monoxide was present in the gases as compared with 0.8% of carbon monoxide in the cement flue gas analyzed, shows the clay flue heater to have obtained much better combustion than the heater attached to the cement flue.

In Part A, with the carbon dioxide content of the gas taken from the clay flue, lower than that in the cement flue gas, it would seem on this basis alone, that the cement heater had the better combustion. Exactly the opposite is the case. When the much higher draft in the clay flue is

taken into consideration it can be readily seen that in reality much more carbon dioxide is being produced by the "clay" heater from the same amount of gas as was being consumed by the "cement" heater. That is, if for the purpose of comparison, the diluting or additional secondary air were deducted from any given amount of gas from the clay gas flue, its carbon dioxide content would then be found to be greater than that of the same quantity of the cement flue gases. Actual calculations show the gas in the clay flue to have, on a basis of the same dilution, 2.5% carbon dioxide in the No. 1 gas samples as compared with 2.4% in the cement flue gases. The No. 2 gas samples show 2.8% carbon dioxide as compared with 2.6% in the cement flue gases, on a basis of the same dilution of both. This is, of course, further evidence of the better combustion obtained in the clay flue heater.

The better combustion in the clay gas heater, which has been so clearly shown in this test, increases the heat given off by the heater. In previous tests as well as in Part B of this test (no observations having been made in Part A) an accurate thermometer was suspended vertically in the air directly over the center of the heaters. In the previous tests the thermometer bulb was held exactly three inches above the heater and in this test exactly four inches was used. With identical positions of the thermometers and equal rates of gas combustion, the thermometer over the clay flue heater registered in this, as well as previous tests, a consistently higher temperature than that over the cement flue heater.

Note: For calculations see "Power Plant Testing" by J. A. Moyer, page 249.

Conclusions

Through increased draft in the clay flue a greater proportion of secondary air is obtained by the heater, which in turn assures more complete combustion of the gas being burned. In the present test, complete combustion was apparently not obtained in the cement flue heater at any time. In other words, the clay gas flue produced a greater combustion and heating efficiency in its heating appliance than was obtained from an identical gas heater under the same conditions and vented by a cement gas flue of the same size.

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Abrasives

Grinding regulations. ANON. *Engineering*, **122**, 752 (1926).—The British Government Inspector of Factories has issued 2 certificates of exemption from the 1925 Act. The 1st deals with portable grinding, glazing, and buffing machines, and specifies that machines without fixed foundations or suspensions are exempt from the regulations on the grounds of impracticability. The 2nd certificate covers precision grinding machines of the universal, internal, and surface types, and in these cases the regulation is relaxed which relates to the safe peripheral speeds of abrasive wheels below 8 in. in diameter. The exemption is made on the ground that owing to the special conditions under which such machines are used, the safety of persons employed is not affected. H.H.S.

Art

Report of the Art Division Committees. The training necessary for the potter craftsman. ANON. *Bull. Amer. Ceram. Soc.*, **6** [1], 5–8 (1927).—An attempt to outline the training for a craftsman so as to give a basis for developing a group of studies through the general educational committee. The scope of the work and the training requisite for it, artistic, technical, and economical, are discussed. **Charting the field of opportunity for the artist craftsman.** MYRTLE M. FRENCH. *Ibid.*, 8–10.—A survey through many sources of information shows the production of tiles to present the greatest opportunities, with the production of garden ware next. Several other types of products are discussed. **A report on the collection from the Transactions and Journals of interest to potter-craftsmen.** MARION L. FOSDICK. *Ibid.*, 10–12.—Abstracts of papers of interest to potter-craftsmen have been collected and copies made for distribution. A note on the general character of these abstracts is given. **The circulating library.** MARY G. SHEERER. *Ibid.*, 12–13.—A suggestion for the establishment of a circulating library of the Art Division and ways of managing it are presented. **The coöperative shop, its equipment and organization.** A. M. BYRNES. *Ibid.*, 13–17.—The establishment of coöperative shops to enable craftsmen to carry on their individual work, means of organi-

zation and operation thereof, and the essential equipment needed therein are discussed. **The small shop.** E. DE F. CURTIS. *Ibid.*, 17–22.—A description of processes, materials, and equipment used by the author in his small shop which, while not ideal, has stood the test of time is used as a basis for working out the problem of an inexpensively operated shop for the craftsman. **Publicity.** ANON. *Ibid.*, 22–24.—Various agencies through which interest in ceramic art may be stimulated are discussed. E.J.V.

Report of Commission appointed by Secretary of Commerce to visit and report upon the International Exposition of Modern Decorative and Industrial Art in Paris, 1925. CHARLES R. RICHARDS. *Bull. Amer. Ceram. Soc.*, **6** [1], 24–26 (1927).—The genesis and development of the modern movement in art is traced. The exhibits were confined to works conceived in the modern spirit and not based on the older recognized styles. The opinions of the Commission relating to the condition of the United States in this connection are enumerated. **Quantity production in art industries.** HENRY CREANGE. *Ibid.*, 25–30.—A 3-phase system for planning and proportioning a manufacturer's line is propounded and explained. Need for experts in art direction is again emphasized. Various types of work exhibited by the European manufacturers of fine ceramic ware are discussed and the development of this art is traced. Various types of decorative glass developed in the last 30 years are discussed in a general way. E.J.V.

A Near East pottery. MABELL S. C. SMITH. *Bull. Amer. Ceram. Soc.*, **6** [1], 31–32 (1927).—A description of pottery work being done in Jerusalem under the guidance and training of the Near East Relief. The pottery produced goes by the name of "Kutahia." E.J.V.

Permanent exhibit at the executive offices of the American Ceramic Society. Crystalline glazes. Cone 11 porcelain. ANON. *Bull. Amer. Ceram. Soc.*, **6** [1], 33 (1927).—A note regarding contributions to the collection of ceramic wares at the headquarters of the AMERICAN CERAMIC SOCIETY. E.J.V.

Created ceramics. ALFONSO IANNELLI. *Bull. Amer. Ceram. Soc.*, **6** [1], 36–39 (1927).—A discussion of art and artistic products, showing how the spirit of the time and people producing them is expressed in the products. A plea for the production of new artistic things, which are expressive of the feelings and emotions significant to us today rather than imitating Old World works. E.J.V.

Of German glass mosaics. NEUMANN. *Glastech. Ber.*, **3** [12], 448–51 (1926).—A historical discussion of the development of glass mosaics in Germany. The methods of preparation of the materials and the development of over 10,000 color tints and nearly 1,000 gold tints by the glass workers of Treptow are mentioned. E.J.V.

The art glass of Leerdam. K. WASCH. *Glass Ind.*, **8** [1], 5–7 (1927).—The Glass Works "Leerdam" of the Netherlands produce art glass which is the result of coöperative work by the artist and the craftsman. Two types of furnaces, the old fashioned Boetius and the modern chamber furnace, system Hermansen, are used. A brief description of each of the following methods of decorating used is given: cutting, engraving, etching, sandblasting, crackling, painting, and lustering. E.J.V.

Measuring the degree of diffusion of opaque and frosted glasses. ANON. *Glass Ind.*, **8** [1], 17–18 (1927).—Three simple types of apparatus developed by German instrument makers for the classification of opaque and frosted glasses are described and the principle on which each is based explained. E.J.V.

The effect of zinc oxide on the coloring properties of chromium, cobalt and iron oxides. D. S. PILLAI. *Trans. Ceram. Soc.* (Eng.), **25** [3], 209–19 (1926).—This paper deals with the behavior of zinc oxide on some of the wider used coloring oxides: chromium, cobalt, and iron, studied according to the well known triangular system. Three sets of triangular mixtures were prepared: cobalt-chromium and zinc mixture; cobalt-iron and zinc mixture; chromium-iron and zinc mixture. Forty-six color mixtures were ob-

tained. These mixtures were weighed, passed though an 80-mesh sieve, calcined at cone 10, wet ground, lawned through 200-mesh sieve, washed and dried. Underglazes were tried with lead glaze and leadless glaze, on prints and magnesia glaze by painting with gum water and fired at cone 04a; 1% of the color was added to a majolica glaze and fired at cone 06a. The colors were also ground laid and fired in an enamel kiln at cone 010a. Tables were given showing the results. All mixtures gave a very good range of colors and with pleasing tones. All the colors are suitable for underglaze work, on glaze, in glaze and for stains. Zinc oxide in the mixture tones up the cobalt blues and helps form a good range of browns, chocolate, brownish yellow with iron oxide. Chrome green is gradually destroyed by the zinc due to the formation of zinc chromate, the various tones produced being shades varying from green to yellowish gray. Magnesia glaze improves the green tints and the browns are not destroyed. No difference in color effect was noted by changing the body mixtures of the biscuit. R.F.S.

Recent accessions in the classical department. GISELA M. A. RICHTER. *Bull. Met. Mus. Art*, **21** [12] (1926).—Recently acquired terra cottas, glass vases, jewelry, gems, and an ivory piece have been placed in the Room of Recent Accessions. The terra cottas illustrate many varied uses of this material in ancient times. Foremost in artistic value are 3 stamps from Arezzo, employed in the manufacture of the famous Arretine molds of the first century. All are decorated in low relief with familiar subjects. A Nereid riding a sea-horse, a satyr playing the double flutes and beating time with his foot on a scabellum, and a winged genius playing the double flutes. These molds all bear the signature of Perennius, the best known of the Arretine potters, who built up such a flourishing industry and exported their wares all over the Roman Empire, including even Greece, the ancient home of pottery. Numerous fragments of Arretine vases with signature of Perennius, together with inferior local imitations have recently been found in Corinth. Though remains of the ware itself are common, only a few of the stamps which represent the original products of the artists have been preserved. There are some in the British Museum, in Arezzo, in Florence, and in James Loeb's collection near Munich. Terra cotta was extensively used in ancient architecture for roofs of buildings especially in Italy where marble was not abundant and in Greece before general adoption of marble. Many of the early temples of the Acropolis had painted terra cotta rather than marble revetments. We have acquired from an old French collection a number of such early pieces, all antefixes from ridge poles said to have come from the Acropolis presumably from pre-Parthenon temples of the 6th century. Some have their palmette designs painted in black and red fairly well preserved; others show scroll and palmette patterns in relief. Three Roman mural reliefs are exceptionally fine examples, dating from the time of Augustus when the best work of this kind was produced. Such reliefs were used to decorate both outside and inside of buildings. The original gay color has mostly disappeared. The subjects are taken from Greek mythology and they are rendered in a particularly fine manner. Two newly acquired pieces are very good examples of Roman glass such as appeared first in Egypt in Hellenistic times, and are finely preserved. Both are said to have come from Olbia in South Russia. Another acquisition is a magnificent covered jar of onyx glass in purple and white. One of the largest pieces in this technique known, is said to have come from Syria. A few "Tanagra" statuettes are charming additions to the Museum's already rich collection. Besides some very beautiful pieces of gold jewelry from the 6th and 4th centuries B. C. there are 13 engraved gems mostly of the best Greek period. They come from the Wyndham Cook collection. There is also a beautifully modeled foot of ivory, which was once a favorite material for sculptors.

Clay products in ancient Babylonia, with special reference to pottery. EDWARD CHIERA. *Ceramist*, **8** [9], 555–69, (1926).—Ancient Mesopotamia on the great plain

between the Tigris and the Euphrates was entirely devoid of stone. As a consequence, the Babylonians used fired clay for almost every conceivable purpose. A large proportion of the buildings were of sun-dried bricks which makes the work of the archaeologist difficult, as the walls are difficult to trace and crumble on exposure to the air. When the Babylonians took the time to fire the bricks they fired them well. The present natives resort to the ancient ruins when they want good bricks. These old bricks are extremely hard, and are often inscribed with the name of the king for which they were made. C. describes the brilliantly colored glazed brick and tile made by the Babylonians and some of the excavations in which they have been found. The Babylonians used clay as a writing material. Even the sun-dried tablets can be recovered. The art of pottery making was highly developed. Not only vessels but furniture, coffins, playthings, etc. were made from baked clay. Even "bird-cages" are found. The best thin pottery ware was made about the 3rd millenium B. C. Numerous clay tablets giving intimate and complete records of 6 generations in early times have been discovered along with a new type of art in which a stone cylinder is rolled along a clay tablet, leaving a picture in relief. A.E.R.W.

The North State Pottery. I. M. JUSTICE. *Clay-Worker*, **87** [1], 50 (1927). F.P.H.

Josiah Wedgwood and William Blake. B. RACKHAM. *Times Lit. Suppl.*, Dec. 16, 1926.—Distinguishes between the famous Josiah Wedgwood, founder of the Etruria Works, and his second son, also named Josiah, in their relations with Blake. Blake executed the engravings of the Portland Vase included in Erasmus Darwin's "Botanic Garden." H.H.S.

Problems in connection with ancient Egyptian materials. A. LUCAS. *Analyst*, **51**, 435–50 (1926).—Interesting information is given concerning flint implements, faience, glass, Cu, bronze, Au, Ag, mortar, plaster, oils, fats, pigments, varnish, pottery, resinous materials, bitumens, mummy hair color, stone, and textile fabrics which have come down from olden times. (*C.A.*)

BOOKS

Old Glass: European and American. N. H. MOORE. London: Hodder and Stoughton, 1926. Price 2 guas. H.H.S.

Old English Drinking Glasses: Their chronology and sequence. G. R. FRANCIS. London: Herbert Jenkins Ltd., 1926. Price 3 guas.—Systematizes the classification of English glasses, while admitting that there are survivals which may have appeared much later than the generic type to which they apparently belong. A wide knowledge of numismatics stands the author in good stead. The book is illustrated in half-tone by upwards of 380 glasses. H.H.S.

The substance of architecture. A. S. G. BUTLER. With foreword by E. Lutyens. London: Constable & Co. Price 12 *S.* H.H.S.

Complete bibliography of English journals and magazines from 1620 to 1920. London: The Times Co. Price one guinea. H.H.S.

English stained glass. H. READ. London: Putnam's, 1926. Price 5 guas. Divides the whole period into 3 ages: The Age of Reason, 1150–1350; The Age of Sentiment, 1350–1500; The Age of Fancy, subsequent to 1500. H.H.S.

Art and the material. S. ALEXANDER. Manchester: Univ. Press. Price 3*S.* H.H.S.

Alcamenes and the establishment of the classical type in Greek art. C. WALSTON. With 208 illustrations. Cambridge Univ. Press, 1926. Price 30 *S.*—The square-faced type is associated with Phidias and the long-headed one with Alcamenes, the reasons for the latter ascription being drawn from the Olympia pediments. H.H.S.

Cement, Lime, and Plaster

The new era in concrete. JOHN G. AHLERS. *Amer. Arch.*, **130** [2511], 501–506 (Dec. 1926).—A statement and discussion of the water-cement ratio rule as to the strength of concrete, and a report on certain conclusions derived from research work authorized by a Joint Committee of New York contractors, and based on the results of over 100,000 tests made by Duff A. Abrams and his staff in the Structural Research Laboratory of Lewis Institute. The dependability of the water-cement ratio rule is asserted, some methods of practical application of the rule in the field are described, and its general usefulness made clear as a means of assuring necessary strengths of construction while avoiding needlessly strong and unnecessarily expensive mixtures. Savings of 25 to 40 cents per cubic yard of concrete are claimed as a result of its use. An outline diagram is given of a simple and inexpensive device for applying this rule together with a chart or graph giving the relations of the water-cement ratio to the strength of the concrete, and some data on tests actually made of concrete mixed by this rule. Illustrated. W.H.W.

The manufacture of Portland cement. J. H. JENNINGS. *Chem. Eng. Min. Rev.*, **19,** 17–20 (1926).—Gives a description and diagrammatic layout of the new plant of Australian Cement Ltd., at Fyansford, Victoria. M.E.M.

Consistence of cement pastes, mortars, and concrete. N. DAVEY. Dept. of Scientific and Indus. Research. *Building Res. Tech. Paper*, No. 5 (1926).—When a sufficient quantity of suitable liquid is added to an insoluble or partially insoluble substance in a finely divided solid state, the particles will cohere and the mixture will acquire plastic properties; in other words, it will flow under the action of external forces and be capable of being molded. If the quantity of liquid is small, the particles may only possess a very limited degree of cohesion and the application of even very small external forces may cause the mixture to crumble into separate masses. The workability depends primarily on the amount of water added; but it is unsatisfactory simply to use percentage amounts of water as criteria. Different materials require different amounts of water to give maximum strength, minimum permeability, or even desired plasticity. The way out of the difficulty seems in the study of consistence, *i. e.*, the general physical state of the material when rendered plastic by the addition of water. (1) Investigate what factors affect consistence, besides the most obvious one—the percentage amount of water, (2) Investigate the effect of strength of each of these factors, (3) Investigate various methods of measuring consistence, and find which of these is most suitable for the ranges required both for practical work and for laboratory work. D. shows that various factors are involved and that for an ideal specification, in addition to consistence, such factors as method and time of mixing should be specified. The consistence of the mix and also the strength of the resulting product depend on these factors. A summary and recommendation are given at the end of the paper. While it is not considered that finality has been reached, it is hoped that the data here collected may help to draw attention to the importance of the subject both from the standpoint of the amount of water to be used in practice and also that to be used in laboratory testing. The paper is well illustrated and contains a valuable bibliography. O.P.R.O.

Reclaiming and the decrease in crystallization of the insoluble form of $CaSO_4xH_2O$. P. P. BUDNIKOFF. *Tonind. Ztg.*, **50,** 1475–78 (1926).—The poor setting properties of recalcined plaster of Paris is due to the insoluble form of $CaSO_4xH_2O$. If it were possible to hydrate the insoluble material, old plaster of Paris which had set might be used over again after calcining the same. The amount of insoluble $CaSO_4xH_2O$ is dependent upon the calcination temperature, time of calcining, and the fineness of grain of this material. A long uneven calcination of gypsum favors the formation of the

insoluble anhydrite which harms the setting of the plaster. The deterioration in strength of old plaster of Paris is due in part at least to the dehydration of the plaster and the formation of the insoluble form. H.G.S.

[**Supercement.**] **Certain cements and their properties.** J. F. GODDARD. *Can. Engineer*, **51**, 710–12 (1926).—Following a description of Portland cements, their chemical constituents, and the effect of regaging, G. proceeds to supercements made by adding "Catacoll" to Portland cement clinker during grinding. Catacoll is a gypsum treated with tannic acid, and it is substituted for an approximately equal amount of the raw gypsum ordinarily added to the clinker at the same stage. Supercement was first used by the British Government during the war for the construction of fuel oil and petrol storage-tanks. The tests showed that 1 : 1 supercement mortar was impervious to aviation spirit at press. 50 lbs. per sq. in. Leaner mixes, 3 and 4 to 1, have stood up to 175 lbs. for some months. The mixture recommended is 1 pt. supercement : 1½ sand; 3 ballast, with a rendering in 2 coats of 1 : 1 supercement and sand. Catacoll is not a water repellent and by itself has no cementing value. The function of the tannic acid is to facilitate the reactions which occur between the mixing water and the cement. Photomicrographs show that there is always a large % of unhydrated particles in gaged Portland cement. At the age of 3 months, 30% of Portland cement grains were hydrated, whereas 70% of the supercement had reacted with water. It is by this means that supercement attains its waterproofness. H.H.S.

A cement query. ANON. *Chem. and Ind.*, **45**, 961 (1926).—A cement, or sealing material, is asked for, which, when applied to an aluminum container in a cold form, will withstand boiling water for 3–4 months and then be removable without violent mechanical means. H.H.S.

Talks on plaster and foreign plants feature New Jersey meeting. ANON. *Ceram. Ind.*, **8** [1], 68–72 (1927).—A report of the annual meeting of the New Jersey Clay Workers Association. F.P.H.

A new cheap cement for floors and wall plastering. R. HEILINGÖTTER. *Chem. Ztg.* **50**, 704 (1926).—Referring to a paper by Greenbaum (*Ceram. Abs.*, **5** [10] 297 (1926) H. points out that the ratio 1 : 6 used for the manufacture of "Steinholz" tiles is too low. It has been proved that Sorel cement has optimum properties for a ratio $MgCl_2 : MgO =$ 1 : 2.4 to 1 : 2.7. Too large a ratio gives hygroscopic material; too small a ratio gives a brittle end product. The best compressive strength is 275 to 350 kg. per sq. cm. **Reply.** F. R. GREENBAUM. *Ibid*, 704.—For the purpose intended the compressive strength of 105 kg. per sq. cm. was sufficient (1 : 6 mixt.) and advisable for economical reasons. (*C. A.*)

Enamels

Flotation of enamels. ANON. Bur. Stand., *Tech. News Bull.*, No. 116, p.4 (1926). —This investigation includes the study of factors affecting the consistency of enamel slips in order to control their working properties. Four conclusions are given relative to mobility and yield value. R.A.H.

Furnace and smelting developments. F. M. BURT. *Ceram. Indus.*, **8** [1], 49–51 (1927).—B. traces history of enamel furnace and smelting progress and shows how the price of fuel effected changes in design. F.P.H.

Cast iron research. ANON. *Chem. and Ind.*, **45**,943 (1926).—The British Cast Iron Research Association has issued its 5th annual report. The director is J. G. Pearce. Research is conducted in the Association's own laboratory at Birmingham, in several university laboratories, in the Natl. Phys. Lab., and at the works of several members of the Association. More than £6000 was spent on research last year, and this figure will be exceeded in future years. Among the subjects investigated were: (*a*) cupola mixtures

resisting corrosion more than ordinary gray iron, and yet capable of being machined, and possessing good mechanical properties; (*b*) formation of graphite in a synthetic cast iron, so as to control the size and distribution of the particles of graphite; (*c*) production and treatment of malleable cast iron. H.H.S.

BOOK

Progrés de la Fonderie: Moulage et Fusion. C. DERULLE. 256 pp. Paris: Masson et Cie., 1926. Price 22 *f.*—A new addition to the *Encyc. Léauté* technological publications, dealing with foundry practice. H.H.S.

PATENT

Enamels. I. KREIDL. Brit. 245,757, Jan. 10, 1925. White oxides of metals not ordinarily used as opacifying media for enamels are rendered suitable for this purpose by converting them into colloids in the form of a gel, preferably in a colloid mill. Oxides of Sn or Zr or NaOAc or similar compounds may be added to prevent the colloidal substance from dissolving in the enamel mixture. (*C. A.*)

Glass

Some observations on heat transfer in furnaces. D. J. MCSWINEY. *Jour. Amer. Ceram. Soc.*, **10** [1], 1–5 (1927).—Some of the phenomena of heat transfer in glass furnaces are reviewed; it is suggested that circulation of the hot non-luminous products of combustion may be an important factor in heat transfer in furnaces, and evidence is given as to the existence and the rapidity of this circulation.

On the causes of the surface devitrification of glasses. KOZO TABATA. *Jour. Amer. Ceram. Soc.*, **10** [1], 6–22 (1927).—The explanation on the causes of the surface devitrification of glasses upon heating, as heretofore considered, is imperfect. The modes of surface devitrification are greatly influenced by the surface conditions of the glasses. T. gives an interpretation on the causes of this phenomenon of surface devitrification, *i. e.*, the surface contraction which is caused by the surface tension at the glass surface acts most seriously toward the surface devitrification.

The influence of moisture on the mixing of batches for potash-lead oxide-silica glasses. M. PARKIN AND W. E. S. TURNER. *Jour. Soc. Glass Tech.*, **10** [39], 213–20 (1926).—Batches for English crystal using red lead and dry potassium carbonate with varying amounts of added moisture showed greatest ease of homogeneous mixing when containing between 3 and 4% moisture. Batches of lesser moisture content showed segregation, while those of greater moisture content showed increasingly greater difficulty of mixing and screening. D.J.McS.

The effect of moisture on the melting, working, and other properties of potash-lead oxide-silica glass of the English crystal type. E. M. FIRTH, F. W. HODKIN, M. PARKIN, AND W. E. S. TURNER. *Jour. Soc. Glass Tech.*, **10** [39], 220–29 (1926).—Potassium carbonate-red lead-silica batches of between 4 and 4.5% moisture content give most favorable results as regards rate of melting and planing, working properties, homogeneity of glass, uniformity of color, and absence of waviness. Divergence of moisture content from these limits causes marked falling off in rate of melting. Effect of varying moisture content on the working properties of glasses from these batches similar to that found by the authors in the case of soda ash-limestone-silica batches. Results obtained indicate that increase in moisture content of batch increases pot corrosion. D.J.McS.

Glass in the early ages. W. M. FLINDERS-PETRIE. *Jour. Soc. Glass Tech.*, **10** [39], 229–34 (1926).—F.-P. claims no glass made in Egypt earlier than 1500 B. C. All earlier glass imported from Syria. Once established, glass manufacture in Egypt

developed with extreme rapidity. Early methods of manufacture described. Glass early used as material for standard weights. D.J.McS.

A study of the rupture of glass. F. W. PRESTON. *Jour. Soc. Glass Tech.*, **10** [39], 234–69 (1926).—P. gives detailed account of numerous experiments on rupture of glass and analyses of results obtained. Confirms Auerbach's findings that diameter of 'cone' flaws not a function of contact circle of ball used, but adopts Griffith's views that point of beginning of flaw incident to the presence in the glass of some invisible flaw or 'seed' which acts as a focus of action of the stress. Rupture of glass is not decided by any particular stress or strain. 'Cone' fractures actually nearer hyperboloidal in shape, the outcrop being cylindrical. Describes and interprets work carried out along the lines of that of Gabelli on fractures produced by rapid thermal changes. Ribbing due to the intermittent or oscillating advance of a fissure while adapting itself to redistributed stresses. Rate of rupture and consequent character of ruptured surface dependent on excess of strain energy released over that required for increased demands of surface tension. Suggests hackle formation may result from attempt of glass to potentialize as much as possible of the released strain energy. Hackle texture apparently the most generalized form of a fractured glass surface. The more rapid the rupture, the coarser the hackle texture. Suggests geologic columnar structure the result of explosive rupture. D.J.McS.

Old Nottingham glasshouses. F. BUCKLEY. *Jour. Soc. Glass Tech.*, **10** [39], 270–73 (1926).—A history of glass manufacture in Nottingham during the 18th century. D.J.McS.

Opal glasses. J. W. RYDE AND D. E. YATES. *Jour. Soc. Glass Tech.*, **10** [39], 274–94 (1926).—X-ray patterns of opal glasses of varying compositions, sources of manufacture and density indicated that the separated compounds in these were in every case of glass containing fluoride, sodium fluoride or calcium fluoride or a mixture of both. Amount of each compound separating depends on relative amounts of sodium and calcium in the glasses. If any appreciable amount of calcium is present, some of it will separate out as fluoride, while an appreciable separation of sodium fluoride will take place only when the sodium content of the glass is greater than 8%. Microscopic examination shows the particles to be generally spherical in shape, to be present to the number of from 1 to 100 times 10^{12} per cc of glass, and in size from about 1.3μ in the case of fluoride opals to less than the minimum resolvable size. Size of particles depends on rate of cooling, viscosity, and glass composition. The scattering coefficient is roughly proportional to the inverse square of the wave length, except when the particles are very large. Opal glasses are practically transparent to radiation of wave length of about 2.0μ. The absorption of glasses having equal scattering power is less when the particles are large (about 1.0μ) than when they are small. D.J.McS.

The durability of lead glasses and the Peddle generalization. O. KNAPP. *Jour. Soc. Glass Tech.*, **10** [39], 294–99 (1926).—K. suggests use of molecular percentages instead of percentage by weight in investigating the constitution and weathering of glasses, that solubility results be checked by iodeosin tests, and that check solubilities be made on different grindings of the same glass to avoid error due to variations of total surface. Suggests following formula for calculating weathering: Log $w = (\frac{1}{3}R_2O + 0.9)$ where w denotes the weathering and R_2O the molecular percentage of both alkalis. D.J.McS.

The durability of glasses containing zinc. W. L. BAILLIE. *Jour. Soc. Glass Tech.*, **10** [39], 299–304 (1926).—B. criticizes the work and conclusions of A. Mauri who claimed that the results of autoclave tests on a number of commercial ampoule glasses showed that glasses containing zinc are specially liable to attack when subjected to the action of superheated steam. B. points out that all the glasses tested by Mauri which con-

tained zinc and which showed attack were, at the same time, lower in silica and higher in alkaline oxides than the glasses which did not contain zinc and which did not show attack in the autoclave tests, and that Mauri's results could be as readily ascribed to these differences as to the difference in zinc content. Three specially made glasses tested by Mauri, having approximately the same contents of silica, boric oxide, alumina and soda, but a zinc content varying from 0.0% to 5.5% and a corresponding lime content gave indication that the presence of zinc or its substitution for lime might lessen the resistance of the glass to the action of superheated steam. D.J.McS.

The relationship between chemical composition and the resistance of glasses to the action of chemical reagents. Part 1. V. DIMBLEBY AND W. E. S. TURNER. *Jour. Soc. Glass Tech.*, **10**, [39] 304–58 (1926).—Tests made on glasses of 3 types: (1) a set of 2 component glasses containing silica and soda, (2) a series of glasses of the general formula—$6SiO_2(2-x)\ Na_2O,\ xRO$ (or R_2O_3 or RO_2) in which one of the oxides Al_2O_3, TiO_2, ZrO_2, CaO, MgO, ZnO, BaO, and PbO was the third constituent, and (3) a set of 3 component glasses in which the basis of percentage by weight governed the relationship of the oxides. Reagents used were boiling water, 20.24% hydrochloric acid, 2 *N*-sodium hydroxide and 2 *N*-sodium carbonate solutions. Tests were made on 10 grams of glass, ground and screened to 20–30 mesh, contained in platinum or silver gauze, and treated for one hour with 500 cc of reagent. With the first series of glasses, increasing the soda content and decreasing the silica caused rapid decrease in the resistance of the glass to water, hydrochloric acid, and sodium carbonate. Action of glasses with sodium carbonate and hydroxide solutions showed marked contrast, the action of the first resembling closely that of water, while the caustic soda solution showed little variation with variation in the soda to silica ratio of the glasses. In the second series, glasses containing lime as the third oxide showed rapid increase in durability against water, hydrochloric acid and sodium carbonate solution, but not against caustic soda solution, with increase in the lime until the content of this oxide reached 7–8 molecules per 100 molecules of silica, when with further increase in the lime, the increase in durability showed an accelerated decrease. On substituting barium oxide for lime, the durability of the glasses against water, hydrochloric acid, and carbonate solution shows a marked decrease from that of the corresponding lime glasses, but the resistance against sodium hydroxide shows some improvement over the corresponding lime and magnesia glasses. Resistance of soda-lead silica glasses against water and hydrochloric acid shows marked increase on substituting lead oxide for silica up to a content of about 6 molecules of lead oxide per 100 of silica and then increases more slowly. Action of hydrochloric acid is less than that of water up to a content of 19% lead oxide and is greater than that of water on glasses of higher lead content. Caustic and carbonate solutions show about the same action on these lead glasses, the action of these reagents being almost uniform with varying lead to soda ratio. Glasses containing magnesia as the third constituent show somewhat greater durability than the corresponding lime glasses; those containing zinc show marked resistance to water, hydrochloric acid and carbonate solution, the resistance increasing up to a content of about 10 molecules zinc oxide per 100 molecules silica and remaining almost constant with further increase in zinc oxide content. The alumina soda glasses show rapid improvement in durability towards water, hydrochloric acid, and sodium carbonate with replacement of soda by alumina up to an alumina content of about 10%. The action of caustic soda on these glasses is uniform throughout the series and is high compared with other glasses of this type. A series of glasses in which zirconia replaced soda showed higher resistance to these reagents than was shown by any other series of this type, especially as regards resistance to caustic soda. The same is also true of a series of glasses in which zirconia replaced silica, the percentage of soda remaining constant. Authors give a

detailed account of action towards reagents of soda, boric oxide, silica glasses of varying compositions and of condition of treated glasses. In the general effect of the oxides tested in the resistance of the glasses towards water, zirconia gives the best results, followed by alumina and titania, then zinc and magnesia, lead oxide, lime, and barium oxide, in the order named. In resistance towards hydrochloric acid, the order of effectiveness is, zirconia, alumina, zinc, lime, titania, lead, magnesia, and barium oxide. Towards sodium carbonate solution the barium glasses are the least resistant, then those of lead, magnesia, titania, alumina, zinc oxide, and zirconia. The zirconia glasses are by far the most resistant towards sodium hydroxide solution, then those of lime, zinc, magnesia, barium, alumina, and titania, the last being by far the poorest. Results of solubility tests are given on a large number of different types of commercial glasses. D.J.McS.

The resistance of glass to chemical attack. B. P. DUDDING AND W. SINGLETON. *Jour. Soc. Glass Tech.*, **10** [39], 358–63 (1926).—D. and S. present data on resistance of glasses to boiling water, hydrochloric acid, caustic soda and sodium carbonate solutions, which, in the main, confirm the results obtained by Dimbleby and Turner. D.J.McS.

Viscosity of glass. ANON. Bur. Stand., *Tech. News Bull.*, No. 116, p. 2 (1926).—The method of determining viscosity consists of measuring the force required to produce rotation of a cylinder partially immersed in molten glass at definite temperatures. Rotation was produced by means of falling weights suspended over 4 pulleys by a string wound around a drum. The drum is fixed to the shaft carrying the cylinder. Certain changes which were made to this apparatus due to large variation in friction with varying actuating loads are described. R.A.H.

Vitaglass, the new window. ANON. *Ceram. Ind.*, **8** [1], 45–46 (1927).—Vitaglass is a true glass of high quartz content to which certain rare elements have been added. Vitaglass transmits light to the extreme range of the sun's spectrum, and somewhat beyond. The actinic rays, the basis of heliotherapy, are thus available for indoor application. F.P.H.

Problems glass men want solved. C. H. MODES. *Ceram. Ind.*, **8** [1], 44–45 (1927).—A plea is made for better glass tank refractories. Furnaces that will produce more glass to the square foot of melting area needed. A cheap gas is needed. F.P.H.

Problems of the glass industry discussed. C. H. MODES. *Amer. Glass Rev.*, **46** [16], 15–16 (1927).—A discussion of various forms of glass, based on the fact that glass is essentially a material which, on cooling from a state of viscous body, has failed to crystallize. The need for more fundamental research in glass is stressed. The general limitations of glass compositions are mentioned. The need for better refractories, better furnaces, better and cheaper fuel, and higher productivity is discussed. Vocational studies connecting college class room work with actual plant experience are urged. E.J.V.

Chance Bros. "Calorex" glass and Vitaglass. ANON. *Amer. Glass Rev.*, **46** [15], 27–28 (1927).—Two new kinds of glass are described. "Calorex" is of such a character it cuts off about 83% of the heat from the sun while transmitting about 65% of the light. Vitaglass allows ultra-violet rays down to 2750A to pass through it. The rays below 3100A appear to be valuable rays, intimately associated with metabolism and growth, therefore Vitaglass is of therapeutic value since it allows these rays to pass. Excerpts of reports regarding tests of these glasses are given. E.J.V.

Some aspects of current plate glass practice. IRVING E. ADAMS. *Glass Ind.*, **8** [1], 1–4 (1927).—The composition of polished plate glass batches is discussed, the effect of varying the amounts of the various constituents from those given in a normal batch being pointed out. General comments are made on the choice of raw materials. The problems presented a manager by the demand for quantity production of a high quality

material are enumerated. A typical melting cycle is described in considerable detail. The importance of accurate knowledge of absolute temperature and its proper control are stressed. Common defects, such as ream, or cord, string, drop, or knot, fine seed, bubble, etc., are discussed. E.J.V.

Temperature gradients in the fabrication of machine blown glassware. ROY E. SWAIN. *Glass Ind.*, **8** [1], 8–10 (1927).—The peculiar properties of glass which have been observed and have affected the development of glass working machinery are discussed. Temperature gradients in glass are among the chief problems of the manufacturer of machine made glass. The various types of machinery, accessories thereto, and methods of manipulation to overcome difficulties encountered due to temperature gradients are described and discussed. E.J.V.

Observations and investigations of glass defects. LUDWIG SPRINGER. *Glastech. Ber.*, **3** [11], 395–407 (1926).—There are 3 groups of glass defects which are of greatest interest: (*a*) stony and devitrified glass; (*b*) blistered and bubbly glass; (*c*) decomposed and effloresced glass. Under each group there are several types of defects, such as (1) nodular and fine stoned lime and lead crystal glasses, (2) large stoned hollow glass, (3) large to fine stoned glass retorts, (4) large stoned plate glass, (5) scratched crystal glass, under (*a*); (1) vesicular plate glass, (2) black bubbles in plate glass, (3) "fire white" glass containing a haze of very fine bubbles, under (*b*); (1) decomposed glass tiles, (2) decomposed and effloresced preserve glasses, (3) effloresced antique glasses, (4) unsightly lead crystal glasses, (5) effloresced glasses, especially in oversea transportation, under (*c*). All of these different types are discussed briefly. E.J.V.

Materials for making glass molds. B. STRAUSS. *Glastech. Ber.*, **3** [11], 407–12 (1926).—The material most commonly used for making press or blow molds, or for molds on automatic machines is cast iron. The various kinds of texture obtainable in cast iron due to variation in composition are discussed. Several materials such as chrome-nickel, ingot iron, cast iron, steel alloys, and iron-aluminium alloys are tested for: (1) specific heat, (2) thermal conductivity, (3) mean coefficient of linear expansion between 0° and $t°$, (4) elastic limits at high temperatures, (5) strength at high temperatures, and (6) dilation at high temperatures. A non-rusting, chrome-nickel steel alloy tested seems very desirable for molds but due to the difficulty in working it owing to its hardness, another cheaper, more easily worked steel alloy with less chrome and nickel in it is suggested as very good for the purpose. This latter alloy contains 0.15% C, 15% Cr, and 0.8% Ni. E.J.V.

The silvering of mirrors. BUREAU OF STANDARDS. *Nat. Glass Budget*, **42** [35], 3 (1926).—The cleaning of the surface to be silvered is described in full detail. All chemicals must be of the highest purity. Several different processes discussed are: (1) Brashear's process; (2) the formaldehyde process; (3) Rochelle salts process; (4) second Rochelle salts process; (5) the cathodic process; and (6) the amalgam method. The solutions used in the various processes are enumerated and their preparation and use described. Instructions regarding drying, burnishing, determination of the thickness of the film by using Nobili's rings, and general information are given. Two possible ways to repair damaged mirrors are mentioned. E.J.V

Epochs in glass making. ANON. *Nat. Glass Budget*, **42** [35], 19 (1926).—A historical consideration of the glass industry in 5 epochs, starting with the glass of remotest antiquity and carrying to modern times. E.J.V

Nurre Mirror Plate Co. develops new process for coloring mirrors. ANON. *Nat. Glass Budget*, **42** [37], 3 (1927); *Amer. Glass Rev.*, **46** [16], 26 (1927).—A process for applying non-metal films to silvered mirrors has been patented by Prof. Lyons of Indiana University for the Nurre Mirror Plate Co. It consists of treating the glass or glass substitute with a solution such as gum arabic, rendering the surface wettable with water and

water solutions used in depositing mirror metals, followed by the deposition of a mirror metal. E.J.V

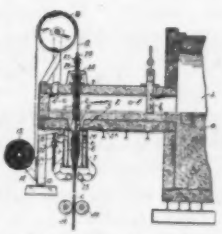
A ten years' retrospect. WALTER BUTTERWORTH. *Pottery Gaz.*, **51**, [594], 1864–71 (1926).—The text, in full, of the Presidential Address given at the Tenth Anniversary meeting of the Society of Glass Technology at Sheffield, on Nov. 16, 1926. E.J.V.

Glass industry in Canada. H. MICHELL. *Indus. Can.*, **27**, 42–43 (1926).—Owing to severe competition from importers, especially Belgium, fewer plants are making glass in Canada today. In 1920 the number of employees was over 4000, it is now under 3000. In 1926 Belgium imported 30.5 million sq. ft. out of a total import of 38.6 million. The Belgian Association of Managers styled the "Mutualité" quotes in dollars and cents, so that the return of Belgium to a gold standard is not expected favorably to affect Canadian industry. M. states that cheap labor cannot be beaten by new processes and greater efficiency of production, and that a tariff higher than the present one of 11¼% is required. H.H.S.

Samsoen's glass researches. ANON. *Chem. and Ind.*, **45**,1001 (1926).—The French Academy of Science Cahours Foundation has been divided between M. M. Samsoen, for his work on glass, and an organic chemist. H.H.S.

The physical properties of glasses. The relationship to chemical composition and mode of preparation. W. E. S. TURNER. *Jour. Chem. Soc.*, 2091–2116, **1926**.—After a historical introduction T. summarizes the relation of physical properties of glasses with variation of chemical composition in some detail. Among previously unpublished data on durability is a summary of the work on BaO, CaO, MgO, TiO_2, ZnO, Al_2O_3, and ZrO_2 in which these materials were substituted step by step for soda in a parent glass of composition $6SiO_2 \cdot 2Na_2O$. The resistant power was determined by per cent loss in weight sustained on boiling in H_2O for 1 hour of a fixed weight of glass powder of a definite grain size. Resistance increases in order of oxides given above. The action of neutral salts and dilute acids is generally similar to that of H_2O. The effect of concentration and of specific oxides, the influence of mode of preparation of glasses and the influence of heat treatment are discussed. The presence of moisture in batch makes glass set more quickly. Remelting shortens the working range of glass and makes it more brittle. A number of curves show comparative effects of different oxides on physical properties. (*C. A.*)

PATENTS



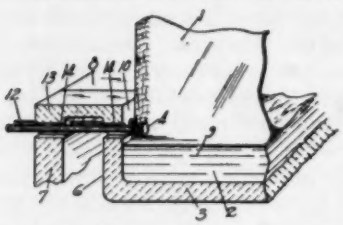
Method and apparatus for making reinforced sheet glass. EDWARD DANNER. U. S. 1,612,419, Dec. 28, 1926. The method of making wire glass by drawing a sheet of wire mesh downwardly and flowing a stream of molten glass evenly and continuously onto each face of the wire mesh, the outer faces of the streams which form the sheet surfaces remaining out of contact with any solid bodies until partially set.

Apparatus for feeding molten glass. L. D. SOUBIER. U. S. 1, 612,658, Dec. 28, 1926. In a glass feeder the combination of a container for molten glass having an outlet opening through which the glass issues, a glass circulating means projecting laterally from an axis at one side of the outlet opening, means for moving the circulating means around the axis of the outlet opening for causing a circulation of glass around the axis of the opening, and adjusting means for varying the effectiveness of the circulating means.

Rotating tube mechanism for glass feeders. Y. TOKUNAGA. U. S. 1,612,756, Jan. 4, 1927. In glass feeding apparatus, the combination, with a container for molten glass having a discharge outlet and having a regulating tube disposed above the outlet,

of a support for the tube and means for removably and rotatably mounting the tube on the support comprising an annular antifriction bearing carried by the support and surrounding the tube near its upper end, an annular plate carried by the upper end of the tube, a member having one end resting upon the support and having its other end bifurcated and provided with rollers resting upon the plate, a screw extending through the member and into a threaded opening in the support, and a spring surrounding the screw between the member and the head of the screw.

Drawing sheet glass. M. J. Owens. U. S. 1,614,082, Jan. 11, 1927. In sheet glass apparatus, a receptacle containing a mass of molten glass from which a sheet of glass is continuously drawn, supplementary walls spaced from the walls of the container, means resting upon the top edges of adjacent walls to create a compartment around the container through which heat may be circulated, and sheet edge engaging means arranged substantially horizontally through the walls for engagement with the edges of the sheet being drawn, the level of the molten glass in the receptacle being a substantial distance below the top of the side walls thereof.



Sheet-glass-bending apparatus. L. D. Blackshere and J. L. Drake. U. S. 1,614,098, Jan. 11, 1927. In sheet glass apparatus, means for drawing a sheet of glass from a mass of molten glass, rotatable means for deflecting the sheet from one plane to another, and means for preventing the deflecting means from falling below a predetermined speed of rotation.

Drawing flat sheet glass. E. T. Ferngren. U. S. 1,614,110, Jan. 11, 1927. The process of reheating a sheet of glass, consisting in applying a series of flames to the sheet surface, and oscillating these flames to equalize the distribution of heat.

Glass forming machine. T. H. Sloan. U. S. 1,614,632, Jan. 18, 1927. In a machine for preparing glass blanks for blowing, the combination of a marver, a rotary carrier provided with a blow pipe having its outer end adjacent to the marver, connections for rotating the blow pipe including a pair of driving disks and a driven disk arranged between them, means controlled by the rotation of the carrier for moving the driven disk with relation to the driving disks to change the direction of rotation of the blow pipe, and means controlled by the rotation of the carrier for moving the driven disk radially of the driving disks to vary the speed of rotation of the blow pipe.

Cleaning the bottoms of crucibles or clay pots. Frederic Merian. U. S. 1,614,928, Jan. 18, 1927. In a machine for cleaning melting pot bottoms, a plurality of scrapers resiliently mounted on oppositely horizontally extending arms, means for yieldingly mounting the arms, means to revolve the arms, the arms being rotatably mounted for movement in a horizontal plane and slidably mounted for linear movement in a vertical direction, means to raise the arms and scrapers vertically so that the scrapers will contact with pressure on the lower surface of the pot.

Glass feeder. L. D. Soubier. U. S. 1,614,936, Jan. 18, 1927. The combination of a container for molten glass having an outlet opening in the bottom thereof, a regulator in the glass about the outlet, a wall surrounding and spaced from the regulator, the wall extending from the surface of the glass substantially to the floor of the receptacle, and provided with an opening at one side thereof below the level of the glass through which the glass is guided into the space between the wall and regulator.

Glass containing germanium. L. M. Dennis. U. S. 1,607,817, Nov. 23, 1926. A transparent glass is prepared by heating together a mixture of a Ge compound such as the dioxide with a compound of a basic element such as PbO and K_2CO_3 which will react

with the Ge compound to form a homogeneous transparent fluid. Glass thus produced is suitable for optical uses. (*C. A.*)

Sheet glass. H. M. BLACK. U. S. 1,608,644, Nov. 30, 1926. A stream of molten glass is deposited upon a rotating drum, then removed from the drum and passed between rolls. (*C. A.*)

Glass. SIBOR SOC. ANON. VERRERIES DE ROMONT. Brit. 245,131, Dec. 21, 1924. In making Na-Al borosilicate glass, $Al_2(SO_4)_3$ is used as a batch material to lower the melting point. A batch for making glass for high-voltage insulators may be formed from sand 81, crystallized $Al_2(SO_4)_3$ 20, crystallized borax 28, and crystallized H_3BO_3 2 parts. (*C. A.*)

Heavy Clay Products

Modern tile making. A. B. SEARLE. *Brit. Clayworker*, **35,** 202–208 (1926).—S. discusses the causes and cures of defects which are likely to occur on clay from extrusion machines. Dog's teeth, rounded notches, blisters, laminations, imperfect shape of the clay, and a curved clay column are among the more common defects. Laminations may often be reduced by inserting a collar between the mouthpiece and the pug mill. H.G.S.

Clamps for roofing tile. ANON. *Tonind. Ztg.*, **50,** 1360 (1926).—A new clamp is described for holding roofing tile to roofs without nails. These clamps are heavily galvanized to make them resistant to corrosion. H.G.S.

A day with the potters. ANON. *Clay-Worker*, **86** [6], 458–62 (1926).—A description of the plant of the Globe Brick Company where paving brick and ladle brick are manufactured. F.P.H.

Making brick and building tile in Texas. ANON. *Clay-Worker*, **86** [6], 473–75 (1926). —A description of the plant of the Waterman Brick and Tile Company. F.P.H.

Simplified brick. ANON. *Clay-Worker*, **86** [6], 484 (1926).—A discussion of a part of the annual report of Secretary Hoover dealing with the standardization and simplification of clay products is given. Paving brick leads the list with a reduction of 94%, that is from 66 kinds and sizes to 4. F.P.H.

Recommended building code requirements for working stresses in building materials. ANON. *Clay-Worker*, **86** [6], 488 (1926).—An abstract of the report of the Building Code Committee of the Department of Commerce. The materials covered in this report are reinforced concrete, cast iron, steel, and timber. Emphasis is placed upon competency of design and the desirability from an economic standpoint of increased personnel and facilities for building inspection. F.P.H.

Interesting historical facts on drain tile. GEORGE M. FRIES. *Clay-Worker*, **86** [6], 490–91 (1926).—F. gives a photograph of samples of drain tile collected in Indiana. Some of this tile has been in use for 80 years. F.P.H.

Plant of the Westfield Clay Products. ANTON VOGT. *Clay-Worker*, **87** [1], 31 (1927). F.P.H.

Factory design and equipment and manufacture of clay wares. T. W. GARVE. *Clay-Worker*, **87** [1], 32–33 (1927).—The first of a series of articles on this subject. This article deals with raw materials. F.P.H.

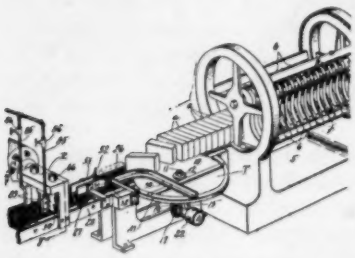
Paving brick prospects brightest in industry's history. ANON. *Brick Clay Rec.* **69** [13], 972–73 (1926).—Manufacturers consider advertising and publicity plans and will make Arlington tests the start of new era for paving brick. F.P.H.

Texas' new 24 kiln plant. ANON. *Brick Clay Rec.*, **69** [13] 981–83 (1926).—Description of the new plant of the Waterman Brick and Tile Company. F.P.H.

Firing sewer pipe in 36 hours. ANON. *Brick Clay Rec.*, **70** [1], 35–37 (1927).—A description of the plant and methods of the Roming Clay Products Co. A time-temperature chart is given. The kiln construction is described. F.P.H.

Clay working plants, Quebec, Nova Scotia, and New Brunswick. L. P. COLLIN. Canada, Mines Branch. Invests. in Ceramics, 1926.—C. visited the brick burning and tile plants operating in Quebec, Nova Scotia, and New Brunswick with the view of studying the technical difficulties and if possible to assist the manufacturers in overcoming them. In case of wet clay it was found that addition of a small amount of hydrated lime stiffened the clay mixture with result the bricks were firm and retained their shape. In case of scumming, the bricks were found to be wet when placed in the kiln; when thoroughly dried before setting in kiln, scum was not likely to occur. The shale was found, when well weathered, to be fairly plastic and worked well when tempered with 18% water. The shale in the weathered state was considered good material for manufacture of face brick but could be improved by addition of a small percentage of clay to increase plasticity. The unweathered shale should be weathered a year before sufficiently plastic for manufacture of stiff-mud brick.

O.P.R.O.



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Brick forming mechanism. D. P. OGDEN. U. S. 1,613,567, Jan. 4, 1927. In a machine of the class described, means for forming a column of plastic material, means for cutting the column into lengths, and means for progressively molding certain of the edges of the lengths at the cut faces.

Refractories

The thermal conductivity of some refractories. F. H. NORTON. *Jour. Amer. Ceram. Soc.*, **10** [1], 30–52 (1927).—The problem of measuring the thermal conductivity of materials up to high temperatures has been studied, especially in regard to the sources of error. This investigation has shown that many of the previous determinations of thermal conductivity may have had little precision due to a lack of appreciation of the errors involved. The values of thermal conductivity for a number of refractories are given, as obtained by a new type of apparatus designed to eliminate to a considerable extent the errors of measurement. However, it is believed that these values may have an error as high as 25% for the better heat conductors; so that there is still much work to be done in developing a method for measuring thermal conductivity with the precision usual in other physical measurements.

Electric furnaces in the iron and steel industry. H. M. BOYLSTON. *Fuels and Fur.*, **5** [1], 17–30 (1927).—Electric furnaces for steel-making consist essentially of a box-like hearth of steel plates lined with fire brick and other refractory material. An arched roof of fire brick with holes for the introduction of electrodes is usually placed above the hearth. The lining of the furnace may be either of silica, in which case it is called an acid lining, or of burned magnesite or dolomite usually bonded with tar, in which case it is called a basic lining. The lining, when strongly heated, becomes a monolithic basin free from joints and capable of holding the molten steel. A description of the various types of electric furnaces for steel making, and their principles of operation is given.

A.E.R.W.

Effect of design and construction upon operation of the open-hearth furnace. W. TRINKS. *Fuels and Fur.*, **5** [1], 33–36 (1927).—In a discussion of repairs and maintenance, T. points out that concentrated radiation from excessively hot flames melts brick work very rapidly; gases passing over the baths at excessive velocities pick up "spittings" and throw them against ports and bulkheads, causing rapid wear and erosion; too rapid reactions carry basic spittings to the acid roof, producing rivulets of flux which destroy

the front and back walls and too high a flame velocity causes the flame to be deflected from hills of scrap, eroding the roof at the skew-back. A.E.R.W.

Recent European furnace developments. ANON. *Z. Ver. Deut. Ing.*; *Fuels and Fur.*, **5** [1], 51–56 (1927).—Diagrams, descriptions, and discussions of methods of operation of a number of industrial furnaces, including an enameling furnace and a clay muffle furnace, are given. A.E.R.W.

The thermal expansion of some fused oxides used as refractories. G. E. MERRITT. (Abstract of paper presented at A.E.C.S. meeting, Washington, D. C.) *Fuels and Fur.*, **5** [1], 66 (1927).—The oxides considered were those of silicon, thorium, magnesium, and aluminium. A combination takes place when thoria and zirconia are fused in one-to-one molecular proportions. A refractory made from this fused material gave a lower increase in length than any of the other materials examined. A.E.R.W.

Requirements of refractories for manufactured-gas plants. Part I. SANDFORD S. COLE. *Fuels and Fur.*, **5** [1], 97–98 (1927).—In a water-gas machine the bricks are subjected to fairly high temperatures, the highest being 1300–1400°C. Changes in temperature and clinkering also cause failure. The new clinkering machine greatly reduces liability to failure from clinkering but increases liability to abrasion. Bricks for lining should have small permanent expansion at 1400°C, be able to pass the A.S.T.M. load test (25 lb./sq. in., 1350°C) have a rather coarse texture, be fairly porous, and give a high value on a spalling test. C. specifies limits found to give good practice. The lower the ferric oxide, the greater the resistance to carbon monoxide action. Spalling is apt to take place in the carbureters and superheaters. A brick which absorbs and releases heat rapidly is desirable for checker work. Brick in the generator are subject to the most severe service. Carborundum block have given excellent results. Specifications and recommendations are given. A.E.R.W.

Our tests on mullite refractories. JAMES H. GILL. *Ceram. Ind.*, **8** [1], 47–48 (1927). —The mullite used in these refractories was obtained by calcining cyanite at cone 19. The resultant mullite is formed into shapes such as 9-inch brick and is pressed under a pressure of 30,000 pounds. The brick is then fired to a temperature exceeding the calcining temperature. It shows no deformation when heated to 1450°C for 1½ hours and subjected to 50 lbs. load per sq. in. The mullite brick remains rigid at cone 36. These brick show practically no slag penetration. Results of tests with these brick when used in a glass tank are given. F.P.H.

Heat-insulating materials. J. S. F. GARO. *Chem. and Ind.*, **45**, 956 (1926).—The qualities required of a heat-insulating material are: Low heat conductivity, low specific heat, low specific gravity, suitable mechanical strength, non-inflammability, absence of corrosive action upon metal, and ability to withstand alternate wetting and drying, and heating and cooling, without cracking. For low-temperature ranges, these requirements are best realized by the use of compressed cork formed into sheets and pipe sections. For medium temperature ranges, such as are met with in steam pipes and boilers, a suitable insulation is a blended mixture of basic magnesium carbonate and asbestos. For furnace insulation, a honeycombed brick whose main constituent is kieselguhr is recommended. The paper concludes with a discussion of the factors that decide the most suitable thickness of insulating coverings. H.H.S.

Comparison of temperature diffusivities and conductivities of silica and fireclay refractories. A. T. GREEN. *Gas World*, **85** [Coking Section], p. 10 (1926).—G. examined 19 fireclay and silica brick for conductivity and diffusivity for the temperature range of 600°C to 1300°C. The results obtained were divided into 2 sections *i.e.*, lower range of 600–1000° C and high range of 1100–1300° C. The diffusivity of silica at both temperature ranges was higher than for fireclay brick. The influence of specific gravity upon the conductivity is discussed in detail. The bulk gravity for fire clay is lower

so this tends to give a lower result for the conductivity of the brick. The silica shows a greater rate of increase of diffusivity and thermal conductivity than fire bricks. If silica is poorly fired it is not as good a conductor as fire clay. S.S.C.

The effect of industrial usage on the thermal conductivity of a semisilica material used in coke-oven wall. A. T. GREEN. *Gas World*, **85** [Coking Section], p. 9 (1926).—G. has examined used and unused semisilica material for the physical properties. The used material was in service for 18 yrs. The original analyzed 81.05% SiO_2, 16.35% Al_2O_3, 1.19% Fe_2O_3, 0.05% CaO. The used material showed the shading characteristic of semisilica refractories when in contact with coking coal. The porosity of the used material was lower than the unused brick. The same held true for the gravity. The conductivity and diffusivity of the unused and used materials showed some divergence. The results reported by G. were for the temperature range of 500–1300°C. The used material on the coking face was 10% higher at 500°C than the unused and 22 % higher at 1300°C. Some of the results reported were:

	Diffusivity—C.G.S. units		Conductivity—C.G.S. units	
°C	(unused)	(used-flue side)	(unused)	(used-flue side)
700	.00284	.00300	.00145	.00159
900	.00328	.00350	.00176	.00195
1100	.00380	.00406	.00214	.00237
1300	.00440	.00502	.00264	.00306

S.S.C.

The effect of industrial usage on the thermal conductivity of a semisilica material used in a coke-oven wall. A. T. GREEN. *Trans. Ceram. Soc.* (Eng.), **25** [3], 258–61 (1925–26).—The thermal properties of refractories are derived from investigations, of which unused products form the basis. Owing to the continued effect of high temperatures and, in some cases, appreciable pressures, the constitutions of refractories are considerably altered; and the thermal and other properties also undergo changes. It is apparent from the experiments described that the used product has a higher thermal conductivity than the unused material. At 500°, the used (coking chamber side) material is 10% higher in thermal conductivity than the unused, at 1300° it is 22% higher. An explanation of these facts lies in the consideration of the alteration in the constitution of the material, the alteration in the nature of the porosity. Although there are no very great changes in specific gravity noted, there seems little doubt that the continued use of the material has influenced the constitution. R.F.S.

Alunite deposits of Australia and their utilization. Advisory Council of Sci. and Indus. Commonwealth of Australia. *Bull.*, **3** (1917).—In Australia there are 3 known deposits of alunite. (1) S. Australia. The alunite is of exceptional purity and evenness of composition. (2) S. Australia (Warnerton). Development work has not been sufficient to give definite information concerning this district. (3) Further development required, indications rather favorable. The utilization of the alumina by-product is suggested as of value as a refractory material for furnace linings or the manufacture of refractory bricks, etc. O.P.R.O.

Research in refractories by Laclede-Christy Co. outlined. ANON. *Amer. Glass Rev.*, **46** [16], 22 (1927).—A short account outlining the steps taken by this Company in the conduct of research work for the manufacture of better refractories during the past 23 years. E.J.V.

The influence of molten glass on refractory materials. OTTO BARTSCH. *Glastech. Ber.*, **3** [7], 249–65 (1925).—The need for glass-house refractories which can withstand corrosion and solution is of great importance. Methods of attacking the problem from an experimental point of view, covering physical, chemical, physico-chemical, and petrographic tests, are discussed. The effect of the composition of the melt on the solu-

bility of the refractories is discussed in detail. The physical chemistry of the solution process is taken up thoroughly in 2 ways: (1) the pyrochemical and solution properties of the clays, showing the changes undergone during the heat treatment received by the clays, and (2) the limiting layer, which forms on the refractory surface next to the melt and consists of a layer of corundum backed by mullite crystals in a glassy ground mass. The effect of the refractory materials is taken up from the standpoint of: (1) the physico-chemical properties of the refractories, (2) the structural properties of the refractories, (3) the effect of the pyrochemical heterogeneity, (4) the effect of the physical heterogeneity, (5) the fineness of pores, (6) the coarseness of pores, and (7) the viscosity of the melt and the character of the pores in the refractory. E.J.V.

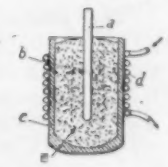
Sagger marls and sagger making (*cont.*). ALEXANDER SCOTT. *Pottery Gaz.*, **51** [594], 1872–75 (1926).—A full report of the discussion which followed the presentation of the lecture by Dr. Scott. See *Ceram. Abs.*, **6** [2], 64 (1927). E.J.V.

Carbonized clay: an acid-resistant refractory. HENRI DU BOISTESSELIN. *Bull. Soc. Ind. Rouen*, **54**, 142–43 (1926).—Carbonized clay, obtained by pulverizing crude clay, mixing with coal and calcining until the clay has reached its limit of contraction, is a powder which can be briquetted by the usual processes. Tests lasting over 4 months in a furnace heated to over 1750° and allowed to cool every night showed no sign of deformation or contraction of the briquets. Carbonized clay is unaffected by HCl and H_2SO_4 vapors, and its hardness is just below that of SiC, making it suitable for the manufacture of abrasive wheels. (*C. A.*)

BOOK

Graphit: Charakteristik, Erzeugung, Verarbeitung und Verwendung. E. RISHKEVICH. 323 pp. Part VII of Chemie und Technik der Gegenwart. Edited by W. Roth. Leipzig: S. Hirzel. Paper 14.50 M., bound 16.50 M. (*C. A.*)

PATENTS



Process for the manufacture of articles in silica glass. HENRI GEORGE. U. S. 1,612,628, Dec. 28, 1926. A process for the manufacture of articles of various shapes in silica glass, consisting in melting the charge in actual contact with a mold, of refractory and conducting material, raised to high temperature by high frequency induction.

Brickmaking. T. C. POND. U. S. 1,612,649, Dec. 28, 1926. Method of making silica brick, comprising as steps mixing comminuted sulphur with diatomaceous earth, molding the mixture, drying the same, then firing, with conversion of sulphur to gaseous phase and concomitant fluxing and fritting of the silica particles with alkaline earths associated therewith.

Method of treating alunite. H. H. MEYERS. U. S. 1,613,238, Jan. 4, 1927. The method of treating alunite and the like consisting in heating a mixture of approximately 500 parts by weight of alunite, about 200 parts by weight of limestone, and about 25 to 50 parts by weight of carbon without melting the same in a rotary-kiln at a temperature of approximately 1100°C to 1600°C for a period of time sufficient to volatilize a large proportion of the potash content of the alunite and to combine the lime of the limestone with the alumina and silica of the alunite to produce a calcium aluminate cement, and recovering the potash principally in the form of potassium sulphate in a Cottrell precipitation apparatus.

Process for purifying, enriching, or refining crude graphite. E. J. E. DUMOND. U. S. 1,614,352, Jan. 11, 1927. The art of refining graphite, comprising crushing the crude graphite, grinding the product wet, sifting the ground material while subjected

to a spray of water, separating the graphite and chemically treating the sifted graphite for removal of residual gangue.

Method of making laminated ceramic articles. G. N. JEPPSON AND M. F. BEECHER. U. S. 1,614,926, Jan. 18, 1927. The method of making a multi-layer ceramic article having a super-refractory facing and a less refractory backing comprising the steps of superimposing a backing of plastic ceramic material and a facing of pre-shrunk refractory granules incorporated with a vitrifiable ceramic bond containing a flux capable of substantially equalizing the shrinkage of the two layers during the firing operation and thereafter firing the mass to bond the granules and unite the backing therewith.

Refractory substances containing zirconium oxide. DEUTSCHE GASGLÜHLICHT-AUER-GES. Brit. 245,101, Dec. 24, 1924. ZrO_2, free from SiO_2 and other impurities, is mixed with 5% or less of an alkaline earth oxide, sintered at about 1300° and then fired at a higher temperature. More porous articles may be formed by wet-molding and firing at 1800–2000° without preliminary sintering. (*C. A.*)

Refractory materials. A. MARKS. Brit. 244,391, Dec. 10, 1924. Refractory material such as MgO is mixed with an oil, preferably of a fatty drying or semi-drying character such as linseed, cottonseed, fish or fat-rendering oil, and the mixture is molded and fired to obtain a compact product having about 22% of voids and a low coefficient of expansion. (*C. A.*)

Terra Cotta

Concerning north German brick architecture. ARTHUR WOLTERSDORF. *Amer. Arch.*, **130** [2511], 477–84 (1926).—A brief history of the development and use of brick in the building industry from 1100 A.D. to the Thirty Years' War. The article is very fully and beautifully illustrated, showing the various decorative features in residence, institutional, and ecclesiastical architecture. W.H.W.

The chimney tops of Antibes. SAMUEL CHAMBERLAIN. *Amer. Arch.*, **103** [2511], 487–92 (1926).—An interesting and instructive illustrated description of the various forms of chimney tops shown among a regiment of such shooting up from the flat, sun-baked roofs of the old city of Antibes. A great variety of ingenious forms is shown, each designed to let out the smoke and keep out the rain. Very many of these are of ceramic or cement construction, and they represent all conceivable shapes from that of a miniature Parthenon to a Chinese lantern, a modern bungalow, or a Pueblo Indian shack. Some are shaped like bird houses while others suggest sentinel posts on the walls of a penitentiary. The various forms shown are rather utilitarian than artistic in character, though possibilities are suggested to the artist in cement or ceramic materials. The article is very attractively illustrated by the author's sketches and by photographs, and incidentally gives a brief but very vivid description of this quaint old city of Italian flavor. W.H.W.

White Wares

A microphotographic study of free quartz in feldspar. A. MALINOVSZKY. *Jour. Amer. Ceram. Soc.*, **10** [1], 23–29 (1927).—The study presented in this article is of the quantity and variations of the free quartz in feldspar estimated by means of microphotographs and calculations based upon them.

A study of the effect of the substitution of calcined ball clay for nonplastic in porcelain and talc bodies. A. S. WATTS, R. M. KING, AND H. G. FISK. *Jour. Amer. Ceram. Soc.*, **10** [1], 53–58 (1927).—It has been the purpose of this study to determine the effect of the substitution of calcined ball clay for flint in certain type bodies. Complete data on the physical properties of these bodies has been obtained, including electrical

resistivity up to 980°C. A substitution of calcined ball clay for a portion of the talc in a type talc body has also been made.

The determination of mullite in a porcelain body. T. N. McVay. *Jour. Amer. Ceram. Soc.*, **10** [1], 62–63 (1927).—An attempt was made to separate mullite crystals in a porcelain by the use of hydrofluoric, sulphuric, and phosphoric acids. Chemically pure mullite was treated in the same manner. The results of such a separation were not satisfactory.

The effect of calcined cyanite in porcelain bodies. Samuel J. McDowell and Edward J. Vachuska. *Jour. Amer. Ceram. Soc.*, **10** [1], 64–72 (1927).—A study was made of the physical properties of porcelain bodies containing varying amounts of calcined cyanite (mullite), feldspar, and flint with a constant content of 50% clay. All bodies were made up under uniform conditions and fired to their proper maturing temperatures which varied from cones 8 to 20. Moduli of rupture for correctly fired bars varied from 5100 to 12,100 lbs. per square inch, those bodies high in mullite being the strongest. The coefficients of linear expansion between 30 and 844°C varied from 4.3×10^{-6} to 6.6×10^{-6}, those bodies high in mullite having the lower expansion. Thirty per cent or more calcined cyanite (50% or more total mullite as figured from chemical composition) must be present to obtain a marked effect on either of these properties. Triaxial diagrams show the position of various typical porcelain bodies and how they might be affected by additions of this material.

Physical properties of porcelain. Anon. Bur. Stand., *Tech. News Bull.*, No. 116, p. 3 (1926).—A study of the fundamental properties of porcelain as affected by various raw materials used and various rates of heating and cooling. Conclusions are given as derived from thermal expansion observations on a body fired to cone 12. Different specimens of the same body were fired in either 16, 30, or 40 hours. R.A.H.

A fundamental study of glaze fit. Anon. Bur. Stand., *Tech. News Bull.*, No. 116, p. 3 (1926).—An investigation is being conducted on the relations of modulus of elasticity, thermal expansion, and tensile strength of whiteware bodies and glazes. A description of the method of determining modulus of elasticity of glazes is given. R.A.H.

Continuous filtering of clay bodies. F. W. Young. *Ceram. Ind.*, **8** [1], 53–54 (1927). —Continuous filtering of clay has never been achieved because it has been impossible to build up a cake in excess of $\frac{1}{16}$ inch, due to the poor filterability of the material. This thin cake could not be properly discharged from the filter drum by means of the scraper used on the old type of continuous vacuum filters. This difficulty is overcome in the new filter by the use of filter cake reinforcement. This consists in building a thin cake around parallel cord reinforcing members so that when the cords are removed from the filter wheel, the clay is stripped off in sheet form. The clay in sheet form is carried to and around the surface of the steam drier which reduces the moisture to the desired content. In wet molding this drier is omitted. Units are being built which have a capacity of 25 tons per day. F.P.H.

Discuss insulator simplifications. Anon. *Ceram. Ind.*, **8** [1], 72 (1927).—The first step in the elimination of waste and the simplification of practices in the manufacture of porcelain insulators has been taken with the establishment of a committee to conduct a survey of present conditions in this industry, it was announced by the Department of Commerce. F.P.H.

The relation of science to the pottery industry. Arnold T. Green. *Pottery Gaz.*, **51** [594], 1876–77 (1926).—A general discussion taking up the various problems which require more study and solution as: the study of clays; the plasticity of clays; the firing of clay wares; arrested reactions and kiln atmospheres; the flow of oven gases; study of fineness of particle and the influence thereof upon properties of fired ware; investigations

on the nature of casting slips; and faults common to cast clayware bodies; the mechanism of the drying of clay wares; properties of plaster of Paris in their relation to the casting operation; and the properties of glazes and bodies in their relation to such faults as crazing, peeling, etc. E.J.V.

Studies of the firing and vitrification of porcelain and whiteware by means of porosity measurement. PIERRE BRÉMOND. *Céramique*, **29,** 217–26 (1926).—B. studied the influence of feldspar and lime upon the vitrification of bodies. He found that high feldspar bodies started to vitrify about 1050°C and the high lime bodies first started to vitrify at 1200°C and then vitrified very rapidly, becoming thoroughly vitrified at 1250°C. In other words feldspar bodies have a long safe vitrification range while lime bodies have a short dangerous vitrification range. H.G.S.

Lead poisoning. ANON. *Chem. and Ind.*, **45,** 952 (1926).—The total number of deaths in England in 1925 due to lead poisoning in the pottery trade was 5, and the average age 58. The 1924 figures were 18, age 52. H.H.S.

Simplification program adopted for white glazed tiles and unglazed ceramic mosaic. ANON. *Ceramist*, **8** [9], 600–12 (1926).—Recommendations are given covering 4 primary features of operation: (1) establishment of uniform grade nomenclature, (2) use of grade marks, (3) formulation of minimum grade specifications, and (4) certification of grades. These features are discussed in detail, their advantages are pointed out and charts showing the proposed markings and the forms suggested for package grade certificates, master grade certificates, minimum grade specifications, and tile contractors specifications are reproduced. A.E.R.W.

The constitution of porcelains. ROBERT SCHWARZ AND HERBERT MERCK. *Z. anorg. allgem. Chem.*, **156,** 1–17 (1926).—The mullite occurring in porcelain is isolated by treating the ground sample with 40% solution, HF at 0°. The low solvency of mullite in this solution was pointed out by Bowen. Porcelain repeatedly fired at 1435° gave only slightly increased content of mullite, indicating that mullite forms at this temperature from the dehydrated kaolinite rather than from the combination of Al_2O_3 with the added quartz. Crucibles fired 4–6 times showed slightly greater resistance to thermal shock than those fired once. Repeatedly fired ware showed little increase in the resistance to fusion mixtures of the alkaline carbonates and sulphates. Mullite may form in the presence of a suitable flux at 1050°, but in porcelain 1300° is not sufficient to form mullite except in very small quantities. Feldspar is found to dissolve over 9% mullite. The presence of excess SiO_2, also soluble, reduces the solubility of mullite. The formation of mullite in porcelain occurs through the combination of Al_2O_3 and SiO_2 either unaffected by the solvent feldspar or as a product forced from solution in feldspar by the solution of excess SiO_2. Microscopic examination of the porcelain pieces supports the latter view. (*C. A.*)

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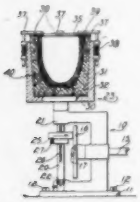


Ceramic articles and method of producing them. A. F. GORTON. U. S. 1,612,916, Jan. 4, 1927. A method of casting a walled article which consists in rotating at a predetermined speed around an axis a body of slip containing portions of relatively heavy material to cause the slip to assume a predetermined shape with the material uniformly distributed therein, simultaneously therewith removing some of the moisture therefrom to retain the material in its uniform distribution, and thereafter removing the remainder of the moisture.

Equipment and Apparatus

Notes on driers for clay products. H. B. CRONSHAW. *Trans. Ceram. Soc.* (Eng.), **25** [3], 221–24 (1925–26).—Various types of driers are discussed, along with the drying

practices of the timber and textile industries such as compartment driers and tunnel driers of the Wolf and Bucyrus type. R.F.S.

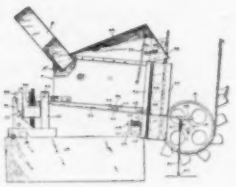
Arc welding—the new method opens possibilities. ANON. *Brick Clay Rec.*, **69** [13], 984 (1926).—A review of a new text book, "Arc Welding, the New Age in Iron and Steel," published by Lincoln Electric Co. of Cleveland, Ohio. F.P.H.

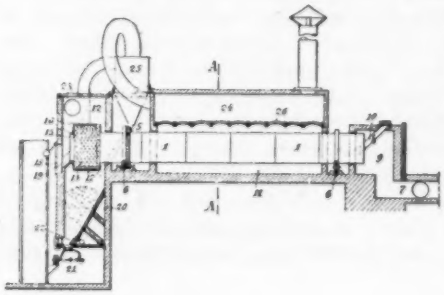
A new apparatus for measuring the fineness of grain of materials. D. C. WEISE. *Tonind. Ztg.*, **50**, 1658–59 (1926).—W. describes a sedimentation method for determining the fineness of grain of cements and similar materials. It is important that the liquid should not react with the material to be tested and therefore water cannot be employed since it reacts with the cement. W. got good results with absolute alcohol. He used 10 grams of material with 90 cc of alcohol. H.G.S.

Measurement of temperature in industrial practice. J. W. HINCHLEY. *Chem. and Ind.*, **45**, 976 (1926).—Every instrument employed must justify its use by improvement in, or reduced cost of, production, or by reduction of fuel, repairs, or time. There are two methods of indicating the temperature of a material: (1) by associating with it an indicating substance which becomes, from a heat point of view, a part of the material, and indicates by some physical property its own temperature: (2) by the analysis or measurement of the radiation from its surface. In the first method, the physical properties available are change in length, strength, volume, pressure, color, electric resistance, potential heat content, physical state, viscosity, and plasticity. Radiation takes place to a far greater extent than is generally supposed; it plays an important part in heat conduction in cases where it has been neglected as of no importance. A thermometer in a room often indicates radiation from the walls, instead of the temperature of the air. H.H.S.

PATENTS

Means for feeding ore elevators. E. J. OUELLETTE. U.S. 1,613,122, Jan. 4, 1927. In a means for feeding material to the ascending buckets of a traction elevator for effecting a substantially vertical lift, a feeder box having an open end proximate to the path of movement of the ascending buckets and means connected with the feeder box at the end of the latter which is remote from the path of movement of the buckets for supporting the box for limited adjustment laterally. In a means for feeding material to the ascending buckets of a traction elevator for effecting a substantially vertically lift, a feeder box having an open end proximate to path of movement of the ascending buckets and side guards carried by the box to extend beyond the open end of the box in flanking relation to the path of movement of the ascending buckets. In combination, a rotary horizontal shaft, a pully secured on the shaft, a belt trained about the pulley and having a substantially vertical ascending stretch, buckets on the outer side of the belt, a feeder box open at the end thereof proximate to the ascending stretch of the belt and supported at its opposite and to swing about an axis parallel to the axis of the shaft, a cam on the shaft, and a jigging bar extending underneath the feeder box and supported at one end to swing about an axis parallel to the shaft and supported at its opposite end on the cam.

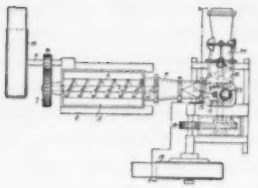




Combined drying and grinding machine for clay and other plastic

materials. GEORGES HIDOUX. U.S. 1,614,364, Jan. 11, 1927. Combined drier and grinder comprising a rotatable drying tube, means for feeding into one end of the tube material to be treated, a drum containing grinding means on the other end of the tube, the peripheral wall of the drum being perforated to form a sieve for the delivery therethrough of the dried and ground material, means for supplying hot gases to the tube and drum and means for retaining within the drum insufficiently ground and desiccated material.

Method of and apparatus for forming articles of plastic material. J. M. LAMBIE AND D. W. ROSS. U. S. 1,614,526, Jan. 18, 1927. Clay treating apparatus comprising a pug mill having connection through a restricted opening with a second pug mill, an auger in the second mill disposed in such position with respect to the orifice that upon rotation of the auger, thin slices of clay will be cut off from the advancing stream, the center line of the orifice being at a point removed from the top of the auger, and an extension at the upper part of the chamber, provided with means for permitting exit of air therefrom.



Kilns, Furnaces, Fuels, and Combustion

Insulation of ceramic kilns. S. E. JOSÉ AND A. E. HUBBARD. *Trans. Ceram. Soc.* (Eng.), **25** [3], 185–99 (1925–26).—It is generally agreed that at least 25% of the heat developed in firing the kiln is lost by conduction through the brick work and by radiation in exposed surfaces. A considerable amount is absorbed in the large volume of brick work used in the walls, bottoms and flues and in the earth upon which the kilns are built. Mention is made of the methods of heat transmission. Under characteristics of insulation are given the properties of the ideal insulation materials for kilns which are of high insulating value, sufficient refractoriness so as not to change the form or lose its efficiency when subjected to high temperatures, sufficient mechanical strength to resist wall strains due to expansion and contraction of the brickwork with changing temperatures, approximately the same coefficient of expansion as the brickwork, light weight which is desirable for crown insulation. A suitable material is found in California known as "celite," and marketed under the trade name "Sil-O-Cel." Methods of determining the rate of conduction through walls, thorough insulation standards in tunnel kiln construction and methods of insulating periodic kilns are discussed. The advantages of kiln insulation are improved quality of firing, reduction in firing time, longer life of crowns, walls, and fire pockets. Data is given on the savings in fuel by proper insulation. R.F.S.

The production of liquid fuels. A. S. FITZPATRICK. *Chem. Eng. Min. Rev.*, **19**, 63–64 (1926).—Describes the Fischer process for the manufacture of Synthol, developed in Germany. Bituminous coal is carbonized at low temperature and the residual coke is used as a source of water-gas. The highly compressed water-gas is passed through an iron tube packed with iron filings which have been impregnated with potash. The tube is kept at high temperature and the exit gases, when condensed, are a mixture of alcohols, aldehydes and low boiling oils, to which the name Synthol has been given. This has given results in internal combustion engines comparable to benzol. The composition can be varied at will by the alteration of pressure, temperature, or velocity of the gases. Its production is not yet on an economic basis. M.E.M.

A highly efficient tunnel kiln. GEO. W. WALTER. *Fuels and Fur.*, **5** [1], 61–66 (1927).—A description of the tunnel kiln recently placed in operation at the brick plant of the Hanley Co., Summerville, Pa. The kiln is 402 ft. long, of the double tunnel type

and has a capacity of 3000 bricks per hr. The gases, on leaving the combustion chamber, move upward and over a baffle wall towards the roof of the kiln from which they are reflected downward to the charge. Each tunnel is equipped with a recuperator. Carbofrax tubes connected between headers form the essential parts of the recuperators. Core-busters consisting of solid cylinders of fire clay with legs for centering compel the air for combustion to pass in contact with the walls of the tubes. The tubes may be replaced without difficulty. The waste gases from the recuperators at 600°F are used in 2 drying ovens. Heat interchange between the cooling chamber of each tunnel and the preheating chamber of the other tunnel is provided for. The hot zones are separated by an air-cooled double wall. At the end sections no separating wall is used. The kiln is well insulated and lined. Cars carrying 1500 bricks are charged every 30 minutes. Each tunnel accommodates 60 cars. A mechanical pusher is used. Bricks are fired at about 2150°F. The fuel consumption is about 6500 cu. ft. per thousand brick. Diagrams and photographs are given. A.E.R.W.

Continuous annealing of malleable iron. GEORGE BLAKNEY. *Fuels and Fur.*, **5** [1], 79–82, 90 (1927).—B. describes a continuous malleable kiln 195 ft. long which is gas fired and equipped with automatic temperature control. A.E.R.W.

Firing brick with boiler furnace stoker. ANON. *Brick Clay Rec.*, **70** [I], 46–47 (1927).—The Massillon Refractories Co. is experimenting with the firing of refractories in a 28-foot downdraft kiln with the aid of an automatic stoker, which it is hoped will give even firings together with the minimum consumption of cheap coal and a minimum of labor cost. Thus far excellent results have been obtained. F.P.H.

High-frequency induction furnaces. F. KÖRBER. *Engineering*, **122**, 755 (1926).—Electric-furnace products are generally regarded as not coming up to the standard of the best crucible products. One reason is that considerable differences may occur in density. Within high-frequency coils, the magnetic circuit is not closed; there is a strong stray field, and violent energy surgings between the current source and the coil may be set up. To suppress these defects, a high-frequency current generator and furnace made by C. Lorenz, of Berlin—Tempelhof was used at the Kaiser-Wilhelm Institute, and the furnace was tuned by means of inductances and a battery of condensers to the generator frequency. The tilting furnaces of graphite are lined with magnesia without any binding material. After two years trial witn 200-lb. charges of steel, these furnaces are considered capable of competing with crucibles. H.H.S.

Renovating the inside of kilns. ANON. *Tonind. Ztg.*, **50**, 1755 (1926).—The inside linings of continuous kilns are usually renovated annually. This is often done by tearing out loose pieces of mortar and repointing the joints with a new refractory cement. A lean fireclay mortar peels off of the brick when spread over the brick. It is claimed that much better results are obtained by spraying the inside of the kiln with a lean refractory mixture. The spray is operated with a hand pump and 2 boys can perform this work. H.G.S.

Systems of oil firing. F. L. BOLT. *Pottery Gaz.*, **51** [594], 1853–63 (1926).—A lecture presented before the English Ceramic Society at Stoke-on-Trent on Nov. 8, 1926. The subject is discussed from a broad standpoint, covering the details of oil storage tanks; pressure system of oil-burning; oil straining, pumping, and heating; oil atomization; air regulation; pressure oil-fired boilers; the steam jet system; steam jet burners; the compressed air system; the low pressure system; a low air pressure oil-fired glass tank; comparisons of respective systems; and oil-firing applied to pottery ovens. Each sub-head is discussed quite thoroughly. A discussion following the lecture is also presented. E.J.V.

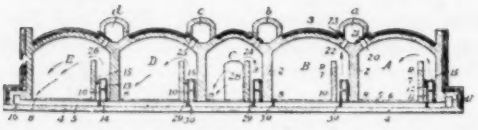
Utilization of waste gases from a glass tank. PAUL R. MEYER. *Glastech. Ber.*, **3** [9], 330–34 (1926).—A discussion of the great amount of waste heat in operating a

glass tank. A plan is suggested whereby 12% of the waste gases can be reclaimed, thereby generating from 100- to 150-horse power hours per ton of coal burned. This heat could be used to good advantage in making steam for gas producers in most factories. Other various uses are also suggested. E.J.V.

Regenerator and burner construction of regenerative furnaces of the iron industries and the practicability of such practice in the glass industry. G. BULLE. *Glastech. Ber.*, **3** [10], 356–74 (1926).—A very complete discussion of the various types of regenerative furnaces, including Siemens-Martin, Amsler-Morton, Cowper regenerators, and others, and how such furnaces could be made adaptable and practical in the glass industry. E.J.V.

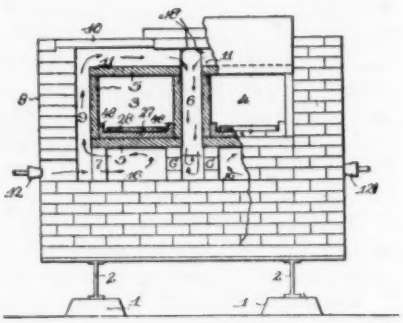
PATENTS

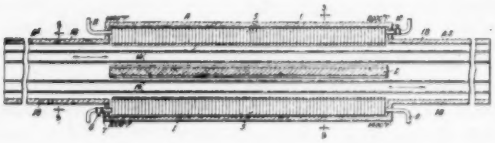
Kiln. B. M. JOHNSON. U. S. 1,612,127, Dec. 28, 1926. In a kiln, a plurality of chambers, a radiating combustion means in each chamber, and means for conducting air in distributed condition from a previously fired chamber into the combustion means of a chamber under fire in distributed condition.



Tunnel kiln. T. C. PROUTY AND W. O. PROUTY. U. S. 1,613,054, Jan. 4, 1927. In a tunnel kiln, a stationary floor constructed of vitrified material, means for applying heat beneath the floor and conveyer means above the floor for moving material to be fired through the tunnel of the kiln.

Tunnel kiln. W. L. HANLEY, JR. U. S. 1,614,470, Jan. 18, 1927. In a tunnel kiln, the combination with a duplex firing chamber having 2 separate firing zones, separated by a longitudinally extending solid wall, a closed heating chamber extending longitudinally through each heating zone, and maintained out of communication therewith, the heating chambers being each provided with a heating burner for delivering products of combustion at one end and being provided at the opposite end with means for conducting the products of combustion from the heating chambers, a unitary tunnel section extending longitudinally from each end of the duplex firing chamber, and parallel goods conveying means movable in opposite directions and each extending through each of the unitary end sections, and through one of the firing zones of the duplex firing chamber.





Geology

The potash-soda feldspars. HAROLD L. ALLING. *Jour. Geol.*, **34**, 591–611 (1926).—The potash-soda feldspars appear to be composed of at least 2 end members, each of which may be trimorphous. The Millard-Michel Levy theory of submicroscopic twinning is capable of explaining cleavage angles of 90° and extinction angles of microcline and orthoclase. This theory does not disprove polymorphism. Evidently these 2

theories are independent of each other. The Millard-Michel Levy theory is not capable of explaining the thermal inversions noted by Des Cloizeaux and by Merwin, nor the cusps in the thermal expansion curves of Kozu and Saiki, nor A.'s findings in the specific gravity and indices of refraction curves. The theory of polymorphism explains these phenomena. Inversion from one modification to another is so sluggish as to require a long time. A. believes that a failure to find a marked difference between Laue-diagrams of orthoclase and microcline does not disprove polymorphism. Vogt has accepted Hadding's Laue-diagrams as disproof of polymorphism. Winchell gives curves of gamma and beta potash-soda feldspars. His curves are based on the necessary assumption that the gamma and beta potash-soda feldspars are single-phase systems and not solutions and mixtures of 2 modifications. Classification of the potash-soda feldspars still awaits proper treatment. Winchell's further subdivision of the plagioclase feldspars is most complete and in strong contrast with the meager classification of the potash-soda series. A.H.K.

Government reports new finds of potash minerals in the Southwest. ANON. *Nat. Glass Budget*, **42** [35], 23 (1926); *Amer. Glass Rev.*, **46** [14], 36 (1926).—A number of potash minerals, including sylvite, kainite, polyhalite, langbeinite and carnallite, have been found in the Southwest and afford increasing evidence of the similarity of American deposits to the famous deposits in France and Germany. E.J.V.

The gypsum deposits of Moose River (northern Ontario). J. LANNING. *Can. Min. Jour.*, **47,** 1172–74 (1926).—It is estimated that 60 million T. of commercial gypsum occur on the Moose near the mouth of the Mattagami. The overburden is 6–8 ft. Analyses are very uniform: CaO 32–33%, SO_3 45–46, H_2O 21–21.6, MgO 0.0–0.7, Fe and Al trace, SiO_2 0.0–0.05%. H.H.S.

James Furman Kemp. C. P. BERKEY. *Science*, **64,** 639–42 (1926).—An obituary of the Columbia professor, author of "Handbook of Rocks," "Ore Deposits of the U. S. and Canada," of many reports of the U. S. Geol. Survey and N. Y. State Survey, and one of the founders and associate editors of *Economic Geology*. H.H.S.

New Zealand Dominion Mining Conference, 1926. ANON. *Engineering*, **122,** 720 (1926).—Papers were contributed dealing with iron, clay, coal, gold, petroleum, and covering various aspects of geology, prospecting, mining, dredging, electrification of plant, and legislation and education. A detailed geological survey of N.Z. by the Dominion Govt. was advocated. H.H.S.

Andalusite. Nova Scotia. L. P. COLLIN. Canada, Mines Branch. Invests. in Ceramics, 1926.—Andalusite is recognized as a valuable ceramic material on account of its extremely high refractoriness, the toughness which it imparts to porcelain bodies, as well as high dielectric resistance. Its principal uses are as an ingredient for spark plug porcelains and vitrified, pyrometer-tube bodies. Workable deposits of industrial importance are rare. For this reason C. investigated the deposits in Nova Scotia, but because of the small percentage of andalusite obtained and the fact that no valuable by-products can be produced, it seems doubtful if the N. S. deposits are of any industrial value. O.P.R.O.

Porcelain clay. Y. OINOUYE. *Geol. and Min. Res. of the Japanese Empire*, p. 104 (1926).—Rocks bearing potash-feldspar such as granite, porphyry, and liparite are widely distributed in Japan. Argillaceous materials for the manufacture of porcelain and earthenware are abundant. O.P.R.O.

Feldspar. OLAF ANDERSEN. *Norges Geologiske Undersökelse Nr.* **128A** (1926).—This publication is a description of the properties, geological mode of occurrence, exploitation, and uses of feldspar, with special reference to the Norwegian feldspar industry. 142 pages, with illustrations and plates. O.P.R.O.

Zeolites and related minerals from Lake Nipigon, Ontario. T. L. WALKER AND A. L. PARSONS. *Univ. Toronto Studies, Geol. Series*, **1926,** 15–19.—Analyses by Rickaby

gave: Diabase from the McDiarmid tunnel, SiO_2 48.16, TiO_2 0.96, Al_2O_3 16.52, Fe_2O_3 1.44, FeO 10.88, CaO 9.97, MgO 9.35, MnO 0.21, Na_2O 2.12, K_2O 0.47, H_2O 0.35, P_2O_5 0.16, sum 100.59%. *Pectolite*, SiO_2 53.28, Al_2O_3 0.16, Fe_2O_3 0.48, MnO 0.33, CaO 33.41, MgO 0.26, Na_2O 9.14, K_2O 0.25, H_2O 2.70, sum 100.01%; specific gravity 2.857. *Prehnite*, SiO_2 42.78, Al_2O_3 25.37, Fe_2O_3 0.87, CaO 26.95, Na_2O 0.30, H_2O 4.18, sum 100.45%; specific gravity 2.900. (*C. A.*)

Chemistry and Physics

Tables to facilitate ceramic calculations. A. MALINOVSZKY. *Ceramist*, **8** [9], 570–80 (1926).—Nine tables are given by means of which the ordinary ceramic calculations in which equivalents and molecular formulas are used can be carried out conveniently and with less chance of serious error. The tables in general give the number of molecules of the different oxides corresponding to certain weights or percentages of common compounds. The numbers are given to a sufficient number of significant figures for most ceramic work, and their use is explained. A.E.R.W.

Anomalous flocculation of clay. H. B. OAKLEY. *Nature*, **118**, 661 (1926).—Further experiments performed in the Wellcome Tropical Research Laboratories, Khartoum, clear up the discrepancies between experiments described in *Nature*, May 1, p. 624, and those of Kermack and Williamson, *Nature*, June 12, p. 824 (1926). The following table gives the time required to flocculate a 0.1% purified clay suspension at various concentrations of sodium and calcium chlorides and hydroxides:

	Time required for flocculation		
Concn. Ca ion	$Ca(OH)_2$	$CaCl_2$	Two equivalents of chlorides to one of hydroxide
0.001	7 hours	14 min.	6 hours
0.002	28 min.	10 "	32 min.
0.003	2 "	7 "	12 "
0.004	1.5 "	6 "	4.5 "
0.005	1.5 "	6 "	3.5 "
0.010	1.5 "	6 "	1.5 "
0.014	1.5 "	6 "	1.5 "
Concn. Na ionn	NaOH	NaCl	NaCl:NaOH=2:1
0.05	2 hours	13 min.	2 hours
0.1	32 min.	13 "	32 min.
0.2	22 "	14 "	24 "
0.5	20 "	17 "	17 "
0.9	15 "	18 "	14 "

These results show that calcium hydroxide is a less powerful coagulant than calcium chloride, and actually tends to stabilize a suspension containing the latter salt, provided that the time of flocculation is longer than about 12 minutes. If the concentration is such that coagulation takes place in 6 minutes or less, then calcium hydroxide flocculates more rapidly than chloride at equivalent concentration. The results for sodium, on the other hand, suggest that even this latter effect should not be called anomalous, as at a concentration 0.9 normal, sodium hydroxide was definitely a better flocculant than sodium chloride, while with the chloride-hydroxide mixture, this effect started at a concentration of 0.5 normal. A preliminary experiment with 0.1% suspension of highly purified amorphous silica gave the following results:

	Concentration required to flocculate in 1 hour	
	Sodium	Calcium
Chloride	No flocculation in 10 hr. in 1 *N* solution	No flocculation in 10 hr. in 1 *N* solution
Hydroxide	0.13 *N*	0.0015 *N*

Thus both sodium and calcium hydroxides were far better flocculants than the corresponding chlorides. O. suggests that if the term "anomalous" must be used, it should be applied to the coagulation of silica by electrolytes rather than to the coagulating powers of calcium and sodium salts. O.P.R.O.

Fired magnesia. (Magnesium oxide, magnesia, caustic magnesia, magnesia usta.) Suggested Stand. Specifications. *Continental Met. Chem. Eng.*, **1**, 61 (1926).—Fired magnesia in the chemically pure condition consists of 60% of magnesium and 40% of oxygen. It is produced by firing natural magnesia (magnesite) or magnesium carbonate precipitated from solutions of magnesia salts. Depending upon the temperature and duration of firing process, 2 different products are obtained, a soft, voluminous and amorphous powder, or a dense, coarsely crystalline, disintegrated mass. Fired magnesia is sold in the forms of, (1) chemically pure, (2) purified, and (3) commercial grade. The technical product is used in the manufacture of artificial stones, concrete, stucco material, ornaments, hydraulic mortar, etc. In view of the fact that magnesite is a natural product, very high demands cannot be made upon the qualities of this material. We propose to fix a minimum purity of 92% MgO, while the maximum contents of moisture and the carbon dioxide content should both amount to 2%. The 2% carbon dioxide would correspond roughly to 4% magnesia carbonate. The most common impurity of the artificially produced commercial grade magnesia is magnesium carbonate, due to either insufficient firing or absorption of atmospheric carbon dioxide. We suggest fixing contents of carbon dioxide at 1% (about 2% $MgCO_3$) and the maximum moisture at 2%. Other impurities are substances soluble in water; since a complete removal of same would mean difficulties, we propose a maximum content of 0.3%. The percentage of lime and of metallic compounds should not exceed 0.1% each. Concerning the "purified" or "twice purified" magnesia the following specifications were proposed: The color must be pure white, solubility in acids perfect, percentage of substances soluble in water not to exceed 0.05%. The maximum carbon dioxide content should be 0.1%, while the total contents of lime, foreign metal, sulphuric acid, traces of chlorine and water not to exceed 2%. O.P.R.O.

Uranium as used in ceramics. H. E. ROEMHILD. *Nat. Glass Budget*, **42** [35], 11 (1926).—By treating chemically the residue of carnotite from which radium has been extracted, the following uranium products can be obtained: uranium oxide, U_3O_8; uranium dioxide, UO_2; uranium trioxide, UO_3; uranium nitrate, $(UO_2)(NO_3)_2+6H_2O$; sodium uranate, $Na_2U_2O_7$; sodium uranyl carbonate, $(Na_2CO_3)(UO_2CO_3)$. The properties and uses of each of these compounds are discussed. E.J.V.

The microphotography of pigments. A. M. MUNRO. *Chem. Eng. Min. Rev.*, **19**, 36–41 (1926).—The use of microphotographs for determining the average particle size, structure, and purity of very finely divided chemicals. O.P.R.O.

Manufacture of whiting. ANON. *Indus. Chemist*, **2**, 489–93 (1926).—A description of the Melton Ross Works of London. Occurrence of limestone; quarrying and crushing of limestone, the levigation process, chalk whitings, and other drying and crushing methods are discussed. O.P.R.O.

Absorptive power of kaolin for gases. DUPRASAY. *Chem. and Ind.*, **45**, 1001 (1926). —Presented by Le Chatelier to the French Acad. Sci. at meeting Nov. 3. H.H.S.

Determination of silicic acid and fluorine in mixtures of fluorite, sand, and silicates. H. DUBIEL. *Oesterr. Chem.-Ztg.*, **29**, 174–75 (1926).—Dry the mixture to constant weight at 250°, cover with HF, evaporate to dryness and again heat to constant weight at 250°. To make sure that all SiO_2 has been volatilized by this treatment, add more HF and repeat. The loss in weight corrected by the gain in weight, occasioned by the conversion of all Fe, Al, Ca, Mg, etc., to fluorides, gives the per cent SiO_2. Next add H_2SO_4, digest on the water bath and finally heat to constant weight again at 250°.

Repeat this treatment with H_2SO_4 to make sure that all CaF_2 is converted to $CaSO_4$. This gain in weight, after allowance is made for the conversion of all fluorides to sulphates, is a measure of the F content. Digest the sulphate residue with dilute HCl, filter, and assume that the residue is now $CaSO_4$. Eventually add the CaC_2O_4 precipitate which is subsequently obtained; to this residue, ignite, digest with H_2SO_4 and finally weigh all Ca as $CaSO_4$. Determine Fe, Al, Mg, etc., in the usual way. This proximate method of analysis has been found to give good results in practice with mixtures containing 40% of F. It does not provide for the presence of sulphides or take into consideration that there is likely to be oxidation of any ferrous Fe and it is unsuitable for the analysis of borosilicates, because with them BF_3 is volatilized. If a carbonate is present, it should be treated first with AcOH after the initial drying, and the resulting $Ca(OAc)_2$ be washed out. (*C. A.*)

Silicon dioxide and its hydrates. ROBERT SCHWARZ. *Z. Elektrochem.*, **32,** 415–19 (1926).—This paper is largely a summary of the information on SiO_2. S. discusses the transformation of quartz to tridymite and cristobalite and reviews previous work on the dehydration of silicic acids. His own experiments cover the vacuum dehydration of silicic acids, measuring at the various temperatures the corresponding aqueous vapor tension equilibrium. SiO_2 was prepared from Na_4SiO_4, Na_2SiO_3, and $Na_2Si_2O_5$, with H_2SO_4 as the precipitant. H_2O is not given off with the same ease at all temperatures. Breaks in the curves do not necessarily correspond to stoichiometric relationships. S. questions the actual existence of orthosilicic acid and is inclined to believe that it is transformed at very low temperatures into metasilicic acid. He does not believe that solutions of Na silicate can properly be considered as systems of free alkali containing colloidal silicic acid. From a study of the Ag salts of the various silicic acids he concludes that they are true compounds and not mixtures of Ag_2O and SiO_2. (*C. A.*)

The measurement of coefficients of expansion at low temperatures. Some thermodynamic applications of expansion data. R. M. BUFFINGTON AND W. M. LATIMER. *Jour. Amer. Chem. Soc.*, **48,** 2305–19 (1926).—The coefficients of linear expansion of Al, Cu, Ag, rock salt, quartz (parallel to the optic axis) and Pyrex glass were accurately determined by an interference method, for temperatures between 90° and 315°K. The coefficients of expansion of the crystalline solids tend to zero at low temperatures and change more rapidly with temperature than do the specific heats. An equation is derived whereby the entropies of 6 monatomic solid metals are satisfactorily calculated and a simple extension of this equation to binary compounds is successfully made. (*C. A.*)

Compounds of the system silicic acid, lime-alumina—their properties and technical significance. RICHARD GRÜN. *Naturwissenschaften*, **14,** 869–73 (1926).—In a triangular diagram the ranges of existence of important mixtures and compounds of the SiO_2-CaO-Al_2O_3 system are shown: near the CaO-Al_2O_3 side (I) alumina cement; near the CaO-SiO_2 side (II) Portland cement, basic and acid slag, glass; near the SiO_2-Al_2O_3 side (III) quartzite, fire clays and brick. System II has 3 compounds, CaO, SiO_2, 2 $CaO.SiO_2$ and 3 $CaO.SiO_2$; β-dicalcium silicate and tricalcium silicate have important binding and hardening properties. In system I, $3CaO.Al_2O_3$, $5CaO.3Al_2O_3$, $CaO.Al_2O_3$ and $3CaO.5Al_2O_3$ are known; tricalcium aluminate in the hydrated form hardens concrete; in alumina cement the other two compounds are essential for the hardening. In system III only mullite, $3Al_2O_3$, $2SiO_2$, is known. Ternary compounds are anorthite $CaO.Al_2O_3.2SiO_2$, gehlenith $2CaO.Al_2O_3.SiO_2$ and jaeneckite $8CaO.2Al_2O_3.SiO_2$. All these compounds are important for fireclay consistency. The technical mixtures are discussed and photomicrographs are shown of several of the compounds present in these products. (*C. A.*)

A simplified slit ultramicroscope. L. V. FOSTER. *Third Colloid Symposium Monograph*, 296–302 (Chem. Catalog Co., 1925).—Description of an instrument de-

signed and made by Bausch & Lomb Optical Co., subsequent to suggestions by Jerome Alexander. The condensing illuminating system (which may hold a tiny mazda lamp) is clamped to the microscope stage and forced against a specially designed cell. (*C. A.*)

Thermoluminescence of potassium feldspar. H. HIRSCHI. *Schweiz. mineral. petrog. Mitt.* **5,** 427–28 (1925).—Eight specimens of orthoclase were examined and found to be thermoluminescent. The apparatus used is described. (*C. A.*)

The adsorption of water vapor on a plane fused quartz surface. The isosteric heats of adsorption of water on silica and on platinum. SAM LENHER. *Jour. Chem. Soc.*, 1785–92 (1926).—The adsorption of H_2O vapor at pressures near the saturation values at temperatures between 290.8°K and 313°K on a plane surface of quartz was measured. Adsorption of this type appears to start at a finite pressure. The silica and alkali content of glass surfaces are important in the formation of the H_2O film on glass. Calculations were made of the free energy changes accompanying the adsorption of H_2O vapor on quartz and also of the isosteric heats of adsorption at constant pressure of H_2O vapor on quartz and on Pt at different temperatures and for different amounts adsorbed. (*C. A.*)

Glass as a fourth state of matter. G. S. PARKS AND H. M. HUFFMAN. *Science*, **64,** 363–64 (1926).—With *n*-PrOH, the softening or "melting" of the glass takes place rather sharply between 90 and 102°K and there is an abrupt 80% increase in heat capacity, as well as an increase in volume. These considerations among others point to glass as the fourth state of matter distinct from liquid or solid but having some of the properties of both (respectively random arrangement, but rigid bonding so that increase in heat capacity is similar to heat of fusion of crystals). (*C. A.*)

A rapid method for determining silica in silicates. SHIGEYUKI SHINKAI. *J. Soc. Chem. Ind. Japan*, **29,** 303–305 (1926).—The method which is based on the fact that when NH_4Cl is added to silica hydro-sol, the latter is transformed into the hydro-gel is applicable not only to pure silicates but also to silicates containing Al_2O_3, Fe_2O_3, CaO, and MgO. After fusing the sample with Na_2CO_3 and treating with dilute HCl in the usual manner, evaporation to a small volume, add 3–4 g. NH_4Cl and then evaporate to dryness with frequent stirring. Boil the residue with 100 cc hot water, filter and wash with hot, dilute NH_4NO_3 solution. (*C. A.*)

Physico-chemical phenomena in ceramics. PIERRE BRÉMOND. *Chaleur et industrie*, **7,** 527–33 (1926).—Review of the more important physico-chemical properties of the raw materials and of the chief phenomena which take place during shaping and firing and even subsequently to the latter. (*C. A.*)

Calculations for a hot-air drier. HACK. *Farben-Ztg.*, **31,** 2934–35 (1926).—A short calculation of the heat, air and steam consumption and of the operating expenses are given. (*C. A.*)

Graphic representation of rock analyses. F. BECKE. *Mineralog. petrog. Mitt.*, **37,** 27–56 (1926).—Quantitative chemical data can be expressed by a point in a geometrical figure, for 2 components a line, for 3 a triangle, and for 4 a concentration tetrahedron. The last can be represented by projections on a plane surface. (*C. A.*)

The separation of zirconium from titanium. LUDWIG MOSER. *Z. anal. Chem.*, **68,** 468 (1926).—Slight corrections and addenda to a previous article. (*C. A.*)

BOOKS

Les ions d'hydrogène: Significance, mesure, applications, données numériques. W. KOPACZEWSKI. Paris: Gauthier Villars & Cie, 1926. Price 40 *f.* H.H.S.

"The Analyst" Decennial Index 1916-1925. Cambridge: W. Heffer & Sons Ltd., 1926. Price 25 *S.* H.H.S.

Sodium sulphate of western Canada: occurrence, uses, and technology. L. H. COLE. Dept. of Mines No. 646. 160 pp. Ottawa: F. A. Acland, 1926. Price 40 *c.*—Sodium sulphate is used in the glass, pulp and paper, nickel refining, textile dyeing, tanning, paint and varnish, electrochemical, and electroplating, medicinal, and chemical industries. The book deals with the occurrence, mineralogy, physical and chemical properties, manufacture, and market conditions. There are 15 plates, 16 figures, 22 maps, and 10 tables. H.H.S.

PATENTS

Production of titanium oxide. P. A. MACKAY. U. S. 1,613,234, Jan. 4, 1927. In the production of titanium compounds, the step of treating damp powdered titaniferous ore with oleum.

Siliceous composition of matter. H. A. ENDRES AND LYLE CALDWELL. U. S. 1,613,448, Jan. 4, 1927. The process of producing a finely divided material comprising heating a mixture of finely divided silica, a hydroxide of an alkaline earth, metal and water; calcining the product of such heating; and chlorinating the product of such calcination in the presence of moisture.

General

A laboratory procedure for determining the drying characteristics of clays. ELBRIDGE J. CASSELMAN. *Jour. Amer. Ceram. Soc.*, **10** [1], 59–61 (1927).—Directions are given for conducting a test for determining characteristics of clays. The reaction of the clays having good, intermediate, and poor drying qualities is described.

Unit organization of ceramists for research promotion. EDITORIAL. *Bull. Amer. Ceram. Soc.*, **6** [1], 1–3 (1927).—A National Ceramic Research Council set up by all the ceramic industries is suggested and the need thereof shown. The probable cost thereof and ways in which it could promote fundamental and special research are discussed. E.J.V.

Need for research and education in the dinnerware branch of the ceramic industry. F. P. JUDGE, JR. *Bull. Amer. Ceram. Soc.*, **6** [1], 34–36 (1927).—While ceramic technologists have accomplished many things in that part of production for which they have been trained, there is a great need for ceramic art and artists. A ceramic art course of study treated from 2 angles; (1) making of articles practical from the manufacturer's standpoint, and (2) having appeal from the consumer's standpoint, is urged, with the suggestion that part of the student's time be spent in the factory so he can get the practical angles of the study. E.J.V.

The Society of Glass Technology celebrates its tenth anniversary. ANON. *Nat. Glass Budget*, **42** [34], 19 (1926).—A brief report of the program and discussions at a meeting held at Sheffield in November, 1926, to celebrate the Tenth Anniversary of the SOCIETY. E.J.V.

The flint glass exhibit at Pittsburgh hotels. ANON. *Nat. Glass Budget.*, **42** [38], 3 (1927); *Amer. Glass Rev.*, **46** [17], 16 (1927).—An announcement of the 47th annual exhibit of the Associated Glass and Pottery Manufacturers being held in Pittsburgh. Details regarding the exhibits of various companies are given. E.J.V.

Researches on the theory of fine grinding. Pt. IV. GEOFFREY MARTIN AND WALTER WATSON. *Trans. Ceram. Soc.* (Eng.), **25** [3], 226–39 (1925–26).—The following conclusions are drawn: (1) The apparatus for elutriating large quantities of sand for air speeds ranging from 2 inches per second to 20 feet per second are described in detail. (2) The compound interest law connecting particle size and number (as described in *Trans.*, **23**, 61, 1924) was confirmed by the fact that Log $\frac{W}{X}3$ plotted against X forms a straight line where W equals weight of a grade, and X equals the

average arithmetical diameter of the particles forming a grade. (3) The grading velocities and particle size of various grades of sand have been determined. R.F.S.

Researches on the theory of fine grinding. Pt. V. GEOFFREY MARTIN, EDGAR A. BOWES, ERNEST H. COLEMAN, AND T. H. LITTLEWOOD. *Trans. Ceram. Soc.* (Eng.), **25** [3], 240–51 (1925–26).—The following conclusions are drawn: (1) Crushed sand, when subjected to careful air elutriation, can be separated into grades defined as "homogeneous," which are characterized by the fact that no matter how often any one such grade is fractionally elutriated, the average arithmetical diameter of the sand particles composing the grade cannot be altered. Neither can the shape of the distribution curve formed by plotting the frequency number of the particles against their diameters. (2) The frequency curve (numbers plotted against diameters) of such a homogeneous grade follows the "probability law": $N=a.b^{-cx^2}$ where N=number of particles composing a grade, x=the diameter of the particles, and a and b are constants. (3) Such homogeneous grades of sand may be considered as composing the units building up the more complex mixtures which form a complete range of particles coming from a tube mill. R.F.S.

The scientific treatment of boiler feed water, introducing the colloidal aspect. W. B. LEWIS AND G. S. IRVING. *Trans. Ceram. Soc.* (Eng.), **25** [3], 200–205 (1925–26).—The various waters used in boilers are discussed along with the impurities which cause hardness. It is shown that the application of colloidal chemistry to feed water problems is of great assistance in reducing boiler scale and corrosion. R.F.S.

Manufacture of clay products and nonclay refractories. ANON. *Ceramist*, **8** [9], 581–99 (1926).—Tables of statistical data relating to the manufacture of clay products and nonclay refractories for the years 1923, 1924, and 1925 are given. Their headings are as follows: I. Number of establishments and value of products for the United States; II. Products by class, quantity, and value, for the clay-products industries, for the United States; III. Clay Products (except pottery), by class, quantity, and value, and stocks on hand, by states, 1925. The total output for 1925 is valued at $447,670,009, an increase of 2.7% as compared with 1924 but a decrease of 0.3% as compared with 1923. The 1925 output is divided as follows: pottery, $112,018,500; nonclay refractories, $20,364,431; other clay products, $314,976,773. Compared with 1924 these represent changes of −5.1%, +12.9%, and +5.0% respectively. A.E.R.W.

The measurement of mechanical power absorbed by driven machines. R. G. PARKER AND D. N. JACKMAN. *Chem. and Ind.*, **45**, 957 (1926).—A recording torsion dynamometer is described which can be applied to existing shafting without necessitating alteration or removal of bearings or pulleys, provided that a clear length of shafting slightly greater than the length of the dynamometer is available. Thus the power consumed by a particular machine may be measured without dislocation of existing arrangements. The torsion in the shaft is measured over a distance of 18 in., and the torque is magnified 250 times by a mirror which throws a beam of light into a moving film inside a camera placed at the driving end of the apparatus. H.H.S.

Things you do not want to miss. ANON. *Brick Clay Rec.*, **69** [13], 976–77 (1926).—A review of articles and subjects of greatest importance covered by the above *Journal* during the past year. F.P.H.

Review of American Face Brick convention. ANON. *Clay-Worker*, **86** [6], 464–69 (1926).—A report of the 15th annual convention of the American Face Brick association. The activities of the Association are discussed. A report of the research committee which has been studying efflorescence, drier scum, and kiln scum is given in brief. The addition of 2% of calcium stearate or ammonium stearate to the prevention of drier scum, the following is recommended; keep the temperature as high as possible,

keep humidity as low as possible, use indicators to indicate the sulphur condition in drier, move air through drier as rapidly as possible, and use minimum amount of pugging water. In regard to the kiln scum the recommendation was made that intelligent lengthening of the firing time would aid in preventing the formation of the scum caused by the sulphur contained in the coal. F.P.H.

Know your costs—send in statistics. ANON. *Ceram. Ind.*, **8** [1], 60–64 (1927).—A report of the 48th annual convention of the United States Potters' Association. Pres. W. C. George gave an account of the outlook in 1927. A. V. Bleininger stressed the need of fundamental research. F.P.H.

Census figures on pottery issued. ANON. *Ceram. Ind.*, **8** [1], 66 (1927).—A summary of data collected by the Department of Commerce on the number of plants and value of output of pottery plants in U.S. F.P.H.

Clay industry's production in 1925 shows big gain over 1924. ANON. *Brick Clay Rec.*, **69** [13], 966–71 (1926). F.P.H.

Twenty-first annual convention of National Paving Brick Manufactures Association held in Washington. ANON. *Clay-Worker*, **87** [1],41 (1927). F.P.H.

Cost accounting in clay products industry. RICHARD C. TURNER. *Clay-Worker*, **87** [1], 37–40 (1927). F.P.H.

Ohio clay men study manufacturing methods of 145 clay plants. ANON. *Brick Clay Rec.*, **70** [1], 47 (1927).—The Ohio Ceramic Industries Association has completed a comprehensive survey of all heavy clay plants in Ohio for the purpose of securing exact information in regard to mining and manufacture of clay industries of the State for record purpose. In collecting the data during the survey the following classes of information were secured: Plant location, products, markets, officers, and capacity; operation (whether full time or part time); clays used with regard to seam and manner of mining; fuels used, and with regard to where it was secured and if mined on the premises; progress of manufacture; kilns, number, kind, and condition; driers, complete description, waste heat if used or not for other purposes; fabrication; temperature control; firing temperatures; firing time; kind of ware produced; an examination of the flow sheet and the problems encountered by every plant. The survey was made by G. A. Bole and H. E. Nold. F.P.H.

Research relations between colleges and industry. A. A. POTTER. *Jour. Amer. Inst. Elec. Eng.*, **45**, 1272 (1926).—Industry has a clear-cut obligation to support engineering research at colleges in order to improve the quality of the college training, to advance basic knowledge in engineering and to increase the supply of trained personnel. (*C. A.*)

Advances in ceramics and their significance for chemical industry. FELIX SINGER. *Z. angew. Chem.*, **39**, 1273–84, 1310–21 (1926). (*C. A.*)

Advances in ceramics in the years 1923-1925. W. FUNK. *Chem.-Ztg.*, **50**, 669–71, 683–4, 702–3, 735–7, 799–801, 827–9 (1926). (*C. A.*)

PATENTS

Method of treating blast-furnace slag. J. M. HILBISH. U. S. 1,614,525, Jan. 18, 1927. The method of converting blast furnace slag into a coherent dense hard mass, comprising adding sufficient red mud to molten blast furnace slag to combine with the uncombined bases of the slag, and permitting the resulting product to solidify.

Fireproofing fibrous materials. T. J. I. CRAIG AND P. SPENCE & SONS, LTD. Brit. 244,503, Aug. 18, 1924. Fireproofing is effected by successive treatment with a solution of alkali aluminate and CO_2 and fixation by immersion in a boiling or "nearly boiling" solution such as Na_2CO_3, NaCl, KCl, Na_2SO_4 or other suitable solution which at atmosphere pressure has a boiling point over 100°. The fixing solution may contain a small quantity of alkali H carbonate. (*C. A.*)

Pottery and brick clays. WALCOT GIBSON. Geology of the Country around Stoke-Upon-Trent. Geo. Survey Mem. 1925. pp. 102.—Besides high-class pottery the district produces much earthenware and sanitary ware of various kinds. It also furnishes an inexhaustible supply of raw materials for the manufacture of "saggers, bricks and tiles." Marls for sanitary ware are variable in quality and few if any show high refractory values. A considerable source of trouble is the presence of minute grains of sphaerosiderite, difficult of detection in unweathered clays. Frequently the same deleterious substances occur in large nodules, necessitating removal before grinding. Etruria marls furnish the main sources of material for blue, brindled and common bricks and tiles. Red marls are used for brick and drain-pipes. Boulder clays furnish abundant materials for bricks and are extensively excavated about Crewe.

O.P.R.O.

BOOK REVIEW

Amtorg Trading Corporation Catalog

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BULLETIN

of the

AMERICAN CERAMIC SOCIETY

A Monthly Publication Devoted to Proceedings of the Society, Discussions of Plant Problems, Discussions of Technical, Scientific and Art Questions and Promotion of Coöperative Research

Edited by the Secretary of the Society Assisted by Officers of the Industrial Divisions

E. DEF. CURTIS, MARION FOSDICK, R. D. COOKE, H. G. WOLFRAM	Art, Enamel	H. L. DIXON, A. N. FINN, L. C. HEWITT, E. H. VAN SCHOICK, H. P. HUMPHREYS, R. F. SHERWOOD	Glass, Refractories, White Wares	OSCAR MATHIASEN, J. R. BOWMAN, D. F. STEVENS, H. R. STRAIGHT	Terra Cotta, Heavy Clay Products

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Vol. 6 **March, 1927** **No. 3**

EDITORIAL

PRESIDENTIAL ADDRESS[1]

BY R. L. CLARE

It is very gratifying to me as president to report that we have just completed the most successful and satisfactory year of our existence.

We laid our plans carefully at the beginning of the year with the avowed intention of running our SOCIETY much the same as a progressive, well organized business is run.

Our chief concern was that of finances. We have been bothered considerably in recent years with our expenditures exceeding our income and we foresaw the financial troubles ahead, if this policy were not changed. Consequently with our income well defined, we planned our budget accordingly. We pared down all unnecessary expenditures, rearranged the *Journal* in order to come within our allowance, and we are making the *Refractories Bibliography* finance itself. By such methods we kept within our budget allowance and finished our year with $2156.00 more to our credit than we had this time last year. This makes our present surplus balance according to the auditor's report $10478.00, which is very gratifying.

Membership growth is the next vital factor in a society such as ours. We certainly are warranted in expecting a normal increase yearly, and

[1] Presented at the Annual Meeting, AMERICAN CERAMIC SOCIETY, Feb., 1927, Detroit, Mich.

if such is not forthcoming, something is wrong, either in the quality of the service we are rendering, or in the way the affairs of the SOCIETY are being handled. I am decidedly against a strenuous membership campaign methods that force members on our rolls who have no real interest in our SOCIETY, and who soon drop out. I believe that we should make our SOCIETY so valuable that it attracts new members. This, accompanied by dignified announcements by our membership committee, should assure us of a constantly increasing roll. There are between 2500 and 3000 ceramic plants in this country alone, all of which could easily afford to maintain corporation memberships. It is our duty to acquaint these various companies of the work this SOCIETY is doing and the value of this work to their particular industry. By such methods we can easily expect a thousand corporation members instead of the three hundred that we have at present. Our record for this past year shows a growth of 237 personal memberships and 34 new corporation members. This is a distinct gain over preceding years, and if our present policies continue, we should continue to grow at an increasing rate. It is a matter of interest to know that a large percentage of these new members send their applications unsolicited to the Secretary's office.

I urge the succeeding administrations, that have the shaping of the policies of the SOCIETY in their hands, to keep the two items just discussed under control. If we continue to live within our income and maintain our present membership gain, our future is bright indeed.

Our various activities during the year will all be fully covered by our committee reports, but I wish to make special mention of the publication of the *Refractories Bibliography*. This is the result of several years of effort on the part of this Committee and is a distinct contribution to our ceramic literature. Professor Parmelee and his Committee are to be congratulated.

We have made a record this year, through our *Journal*, in the number of original papers published, in the abstracts of the world's literature prepared, and in the work produced by our various committees.

It is very evident that the day is not far distant when we will have to consider the services of a full time editor to work in conjunction with our secretary. I recommend this matter for early consideration.

We have two other subjects before us at this meeting of very general interest and which warrant careful consideration by the SOCIETY as a whole. One is the question of ceramic education and its relation to the industry. Are our schools turning out men trained so as to be of the most value to the plants employing them? Our Committee on Educa-

tion has been giving considerable study to this question and will conduct an open discussion of the matter during this Meeting.

The other subject is that of the formation of a research body separate from the SOCIETY as it now functions, but made up of SOCIETY members. The function of such a body would be to direct and correlate all research as now carried on by the various trade organizations at our schools and bureaus, and, by so doing, prevent much useless effort and repetition. The theory of such an organization is good, but the method of procedure is yet to be determined.

In closing, I wish to speak just a word as to the real value of our meetings, and why every man should feel amply repaid for his expenditure of time and money in attending them. Our business meetings are necessary and tiresome; our social meetings pleasant; and our Division meetings distinctly educational. The real value, however, comes from the inspiration that is received. Who can attend one of these meetings and not return to his work fired by a determination to overcome his difficulties, correct his mistakes, and strive just a little harder during the coming year? They pull a man out of the daily grind; they stir his imagination; and give him fresh food for thought. Employers of technical men should realize that meetings such as these furnish just the impetus needed to keep their organization progressive. I think this answers a question that has arisen many times in the minds of some of our plant executives.

ACTIVITIES OF THE SOCIETY

THE 1927 ANNUAL MEETING

The following decisions were made at the Annual Meeting:

(1) To hold the 1928 Annual Meeting in Atlantic City with the New Jersey Clayworker's Association as host.

(2) Not to have a trip meeting in the summer of 1927.

(3) To participate in the Chemical Exposition program next September on "Ceramic Day" at the Grand Central Palace, New York City.

(4) To accept the invitations of the Ceramic Associations abroad, plan a tour for 1928, and solicit support and participation of the ceramic trade associations in this trip.

(5) A Resolution was unanimously approved by the Board of Trustees and accepted by the members assembled without dissenting voice that all money appropriated by Congress for ceramic research in the Bureau of Standards shall be used exclusively in the prosecution of fundamental science researches.

(6) The Secretary shall collect a permanent ceramic product exhibit and a ceramic library, but no funds were provided.

(7) On unanimous vote of the Board of Trustees and the majority vote of the Research Committee and of the Division Officers the question was placed before the members assembled of the SOCIETY officially promoting the organization of an American Ceramic Research Advisory Council. The members voted without a dissenting voice authorizing the Board of Trustees to promote the organization of such a Council.

The several committees reported progress. The Committee on Standards reported several standards approved and soon to be issued.

A bibliography on enamels by R. D. Landrum and associates was announced. It will be published soon.

Bibliographies on whitewares and on ceramic art are nearly completed.

The Annual Meeting was attended by 850 men and 150 women.

OFFICERS OF THE AMERICAN CERAMIC SOCIETY FOR 1927–28

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Officers of Divisions

1927–1928

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Myrtle M. French, Chicago, Ill., Program

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B. A. Ludlum, Noblesville, Ind. }
B. T. Sweely, Baltimore, Md. } Nominations
M. E. Manson, Milwaukee, Wis. }

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C. D. Spencer, Cleveland, Ohio, Vice-Chairman
A. N. Finn, Washington, D. C., Secretary

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H. R. Straight, Adel, Iowa, Secretary
R. A. Horning, Beaver Falls, Pa. } Nominations
C. A. Millar, Mimico, Ontario, Can. }
G. A. Bole, Columbus, Ohio, Program

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R. F. Sherwood, Syracuse, N. Y., Secretary
J. A. Williams, Trenton, N. J. } Nominations
C. E. Jackson, Wheeling, W. Va. }

George W. Denison, Trustee

George Wesley Denison of the Ohio Clay Company, Cleveland, Ohio, has been elected trustee for the Heavy Clay Products Division of the SOCIETY. Mr. Denison has been actively engaged in the clay business for twenty years and during this time has done a considerable amount of pioneering in machinery, plant design, and products. At present he is vice president and general manager of the Ohio Clay Company and treasurer of the Ohio Brick Manufacturers Association.

NEW MEMBERS RECEIVED FROM JANUARY 15 TO FEBRUARY 12

(Members received during the Detroit Meeting are listed separately.)

CORPORATION

Ferro Enamel Supply Co., 2100 Keith Bldg., Cleveland, Ohio.
Federal Phosphorus Company, Ormiston, Ala. J. N. Carrothers, representative.

Illinois Electric Porcelain Co., Macomb, Ill. C. W. Kettron, President.
Leonard Refrigerator Co., Grand Rapids, Mich.
The Standard Dry Kiln Co., Indianapolis, Ind. Robert C. Elliott, Vice President.

PERSONAL

Julius H. Albus, 10125 E. Jefferson Ave., Manager, Pewabic Pottery, Detroit, Mich.
Richard J. Ausfahl, Industrial Engineer (Ferrum S. A., Colon 415), Prov. de Buenos Aires, Argentina.
Alfred E. Badger, Pitney Glass Works, General Electric Company, 1133 E. 152nd St., Cleveland, Ohio.
J. C. Cromwell, 503 Franklin Bldg., Columbus, Ohio.
Eduard Cronn, Hornberg (Schwarzwaldbahn), Germany.
H. B. M. Deurvorst, Ulft (Gld.), Holland.
Alwin C. Eide, P. O. Box 1428, Columbus, Ohio. Sales Engineer, American Zinc Sales Co.
Charles W. Ferguson, Enamel Department, Gurney Foundry Co., St. Lauent, Montreal.
John G. Fritzinger, 4865 Stenton Ave., Philadelphia, Pa., Sales Engineer, The Carborundum Co.
Gordon S. Fulcher, Research Physicist, Corning Glass Works, Corning, N. Y.
Russell Hearing, Claycraft Mining and Brick Co., Columbus, Ohio.
Gordon M. Hutt, Geologist, Development Branch, Canadian Pacific Ry., 525 Newman St., Winnipeg, Manitoba.
William H. Krieg, 530 Riverside Drive, Supt. Mill Dept., Kohler Co., Kohler, Wis.
Karl G. Kutchka, Combustion Engineer, Pittsburgh Plate Glass Co., 609 Whitney Ave., Wilkinsburg, Pa.
Willem G. Lingbeek, General Manager, Chamotte Union, Geldermalsen, Holland.
Robert Long, 3350 Scotten Ave., Assistant Supt., Wolverine Porcelain Enamel Co., Detroit, Mich.
R. C. Meeker, Mandle Clay Mfg. Co., St. Louis, Mo.
Hugh L. Millis, President, Tyler Brick Co., Box 700, Tyler, Texas.
Arthur L. Nelson, Jackson and Moreland, Engineers, 31 St. James Ave., Boston, Mass.
Arthur S. Nichols, Sales Manager, Illinois Clay Products Co., Joliet, Ill.; 805 Transportation Bldg., Chicago, Ill.
Frank Nitzberg, Purchasing Dept., Detroit Edison Co., Detroit, Mich.
Walter M. Ochs, Treasurer and Supt., A. C. Ochs Brick and Tile Co., Springfield, Minn.
Edward W. Oehmig, Supt., Refrigerator Production, Tennessee Furniture Corp., Chattanooga, Tenn.
Tom Maxon Place, Ceramic Engineer, Mt. Clemens Pottery Co., Mt. Clemens, Mich.
John G. Rumisek, Foreman in Burning Dept., Ingram-Richardson Corp., Bayonne, N. J.
William Schassler, Ceramic Production Manager, Parkersburg, W. Va.
Edward W. Scripture, Jr., 873 Ackerman Ave., Syracuse, N. Y. Chemist, Onondaga Pottery.
Edward H. Stehman, Field Engineer, United States Silica Co., 122 S. Michigan Ave., Chicago, Ill.
Vernon B. Stockdale, 609 W. Meek St., Abingdon, Ill. General Supt., Abingdon Sanitary Mfg. Co.
Homer J. Swope, Business Mgr., Economy Enameling Co., Quincy, Ill.
Cuthbert R. F. Threlfall, Firebrick Manufacturer, Lyndhurst, West Hagley, N. Stourbridge, Worcestershire, England.
Joseph O. Whiteley, c/o The Dentists' Supply Co., York, Pa.
Walter Warneke, Washington Iron Works, Los Angeles, Calif.

STUDENT

Vance Cartwright, 4224–9 N. E., Seattle, Wash.
James W. Craig, La Porte, Saskatchewan.
Arthur E. Focke, 139 E. Dunedin Rd., Columbus, Ohio.
Howard H. Mansur, 3925–15th Ave., N.E., Seattle, Wash.
Guy H. Merry, 1749 Chelsea Rd., Columbus, Ohio.
Richard G. Mills, 306 S. Fifth St., Champaign, Ill.
Joseph R. Safford, 324½ Miller Ave., Columbus, Ohio.
Harry J. Sigwart, 728 Beechhurst Ave., Morgantown, W. Va.
Earl Stewart, St. Andrew's College, Saskatoon, Sask.

Membership Workers' Record

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Office	4	Mary C. Stratton	1
		S. D. Swan	1
Total corporation	5	C. F. Tefft	1
PERSONAL		E. J. Vachuska	1
M. G. Babcock	1	W. H. Vaughan	1
T. G. Brown	1	R. T. Watkins	1
W. M. Clark	1	E. Zschimmer	2
Volney Foster	1	Office	7
D. B. Fraser	1		
C. F. Geiger	2	Total personal	33
F. M. Hartford	1	STUDENT	
S. E. Hemsteger	1	W. A. Koehler	1
J. W. Hoehl	1	S. Matthews	2
W. V. Knowles	1	Hewitt Wilson	2
R. D. Landrum	1	Office	4
H. W. Mauser, Jr.	1		
G. V. McCauley	1	Total student	9
T. N. McVay	1		
C. H. Modes	1	Total	47
A. C. Ochs	1		

NEW MEMBERS RECEIVED DURING ANNUAL MEETING
(Detroit, Mich., February 14–19)

CORPORATION

Appalachian Electric Power, Public Utilities, Huntington, W. Va., S. Arthur Wills, representative.
Binks Spray Equipment Co., Mfg. Spray Equipment, 3114 Carroll Ave., Chicago, Ill.
Ohio Power Co., Public Utilities, Coshocton, Ohio. A. S. Durrant, Jr., representative.

PERSONAL

H. W. Arnold, 227 18th Ave., Columbus, Ohio. General Manager, The Winslow Glass Co.
Walter F. Bond, 2000 Elmwood Ave., Buffalo, N. Y. Foreman, mixing and smelting, Enamel Division, American Radiator Co.
H. W. Brewster, 2730 High St., Chicago, Ill.
A. D. Busch, 7540 Lovella Ave., St. Louis, Mo. The W. S. Tyler Co.

Henry de Gallaix, 570 W. 156th St., New York City, Ceramic Engineer, Charles Englehard, Inc.

Frank W. Gilbert, Grinding Abrasives, Rochester, Pa.

Edward N. Horr, 2010 E. 102nd St., Cleveland, Ohio, Assistant Sales Manager, Cowles Detergent Co.

Edward A. McNerney, 11 Kennedy St., Plant Supt., Hanley Co., Bradford, Pa.

Mrs. M. B. Midland, Canadian Clay Co., Readlyn, Sask.

Henry J. Miller, Research Physicist, Nela Research Laboratory, Nela Park, Cleveland, Ohio.

Robert MacDougall, Plant Engineer, Coonley Mfg. Co., Cicero, Ill.

William J. Muhlitner, 1326–28 Penobscot Bldg., Great Lakes Foundry Sand Co., Detroit, Mich.

James T. Murphy, Webster Hall, Detroit, Mich. Cowles Detergent Co., Cleveland, Ohio.

Charles S. Robinson, Cowansville, Quebec.

R. M. Schory, Minerva, Ohio, Manager, Fireproofing Production Dept., Metropolitan Paving Brick Co.

D. P. Smith, Research and Sales Engineer, Penna. Salt Mfg. Co., Wyandotte, Mich.

Lewis Steenrod, Wheeling Steel Corp., Wheeling, W. Va.

Fallmer Stout, Paxtonville, Pa. Paxton Brick Co.

John R. Wasserman, Box 153, Villa Park, Ill. Ceramic Engineer, Wolf Mfg. Co., Chicago, Ill.

Joseph C. Weaver, Clinton, Mich. Ferro Enamel Supply Co., Cleveland, Ohio.

Samuel I. Zook, 2525 Payne Rd., Des Moines, Ia. Supt., Des Moines Clay Co.

STUDENT

Frank J. Ford, Alfred Univ., Alfred, N. Y.

Charles L. Gilder, Alfred Univ., Alfred, N. Y.

F. Marvin Ingoldsby, Alfred Univ., Alfred, N. Y.

William G. Vey, Alfred Univ., Alfred, N. Y.

George L. Williams, Alfred Univ., Alfred, N. Y.

Membership Workers' Record

	CORPORATION		PERSONAL
V. G. Green	1	Frank E. Lauer	1
Roy A. Horning	2	G. V. McCauley	1
		D. A. Moulton	1
Total	3	F. P. Nickerson	1
	PERSONAL	R. F. Sherwood	1
Davis Brown	1	D. D. Schurtz	1
F. E. Hodek, Jr.	1	B. T. Sweely	1
J. W. Hoehl	2	Office	8
J. E. Hutchinson	1		
W. V. Knowles	1	Total	21
		STUDENT	
		F. Westendick	5
			5
		Total	29
		Grand total	76

NEWS FROM MEMBERS OF THE SOCIETY

Robert F. Ferguson writes that his new address is 527 Orchard St., Avalon, Pittsburgh, Pa.

A. F. Gorton is at present associated with Occidental College, Department of Physics, Los Angeles, Calif. His home address is 1054 Grover St., Glendale, Calif.

Fred T. Heath, Manager of the Heath Cube Service, Inc., is now occupying an office at 2525 North High St., Columbus, Ohio.

Clayton S. Houpt, formerly of the Globe Stove and Range Co., Kokomo, Ind., has lately moved to Clinton, Mich., where he is associated with the Ferro Enamel Supply Company of Cleveland.

R. N. Long, is affiliated with the Red Wing Union Stoneware Co., Red Wing, Minn.

O. S. Mundy, has moved from Huntingburg, Ind., to 305 N. Menard Ave., Chicago, Illinois.

Cullen E. Parmelee, who has been employed with the Pittsburgh Glass Company, Creighton, Pa., is now assisting with research work at Mellon Institute, Pittsburgh.

Arthur E. Polk, is living at 3901 S. Morgan St., Chicago, Illinois.

L. M. Richard, is located at Escondido, Calif., Box 271.

PACIFIC NORTHWEST SECTION ELECTS

At the combined meeting of the Pacific Northwest Local Section of the AMERICAN CERAMIC SOCIETY and the Pacific Northwest Brick and Tile Association held in Seattle, Wash., January 14 and 15 the following officers were elected for the year 1927–28:

OFFICERS	TRUSTEES
T. S. Mann, Chairman	S. Geijsbeek, Terra Cotta
J. G. Adderson, Vice Chairman	E. E. Saunders, Refractories
Hewitt Wilson, Secretary	W. J. Howard, Brick and Tile
H. O. Thompson, Treasurer	E. F. Goodner, Sewer Pipe

At the annual banquet which was held at the close of the two-day meeting short talks were given by Ralph P. Stoddard, Secretary of the Common Brick Manufacturers Association, Cleveland, Ohio, T. S. Mann, Hewitt Wilson, and W. L. Howard. Samuel Geijsbeek presided.

A partial list of those who attended the meeting is given below.

H. H. Mansur, Ceramic Department, University of Washington
V. Cartwright " " " "
Joseph Daniels, " "
Milnor Roberts, " "
Hewitt Wilson, " " " "
K. A. Johnson, U.S. Bur. Mines, Seattle
H. F. Yancy, " " " "
S. H. Geijsbeek, Denny Renton Clay and Coal Company, Seattle
Maurice L. Cotta, " " " " " " Portland
H. P. Hassell, " " " " " " Tacoma
E. G. Wulff, " " " " " " Renton
Olaf Olsen, " " " " " " Seattle
H. B. McMillen, " " " " " " Seattle
N. W. L. Brown, " " " " " " Sumas
D. J. Brown, " " " " " " Seattle
S. Geijsbeek, " " " " " " Seattle
S. Geijsbeek, Jr., Seattle

C. A. Houlahan, Builders Brick Co., Seattle
H. O. Thompson, " " " "
Arthur Houlahan, " " " "
F. T. Houlahan, " " " "
T. E. Nicholson, Gladding McBean and Co., Seattle
J. C. Hoskin, " " " " Auburn
Z. Vare, " " " " "
A. A. Carlson, Potlatch Clay Products Company, Potlatch, Idaho
E. W. Dow, San Francisco, Calif. Stevenson and Freeze Machinery Companies
John B. Stirrat, Seattle Brick and Tile Co., Seattle
T. S. Mann, Pacific Stoneware Co., Portland
E. J. Miner, E.J. Miner and Co., Seattle
R. P. Wallace, " " " " "
M. B. Reilly, Pac. N.W. Brick and Tile Assn., Portland
W. J. Howard, " " " " " " Seattle
E. E. Saunders, American Fire Brick Co., Spokane
Peter Erickson, J. T. Davie Brick Co., Mead, Wash.
V. B. Kelsey, Washington Brick Lime and Sewer Pipe Co., Spokane
E. F. Goodner, " " " " " " " Seattle
Harold S. Smith, Seattle
W. F. Wallace, Far West Clay Co., Tacoma
Ralph P. Stoddard, Common Brick Mfgs. Assn., Cleveland, Ohio

NOTES AND NEWS

R. C. PURDY HONORED AT CANADIAN MEETING

At a recent meeting of the Canadian Clay Products Association which was held in Toronto, February 9 and 10, R. C. Purdy, Secretary of the AMERICAN CERAMIC SOCIETY was made a life member of the Canadian organization. C. A. Millar, past president of the Canadian Clay Products Association made the address which is given below.

I have been asked by our executive committee to perform a very pleasing task of doing honor to a man who has been of inestimable assistance to us as clay workers and in the higher class of ceramic work both in the United States and Canada. Once in a while our lives are refreshed and enriched by coming in contact with a man who puts service to his fellow man above rank and fortune for himself and I feel sure you will agree with me that this is one outstanding example. For many years his duties have taken him to all parts of his own country and many times has he crossed the boundary line to assist us on our way to success which has been proven elsewhere was the right way. His has not been the easy road for instead of sitting comfortably at home surrounded with family and comforts he has gone forth wherever assistance was needed. We first hear of him as a professor in Ohio State University at Columbus, Ohio, and for some years he was a prominent member of the N.B.M.A. and convener of many committees which performed excellent work. He has made an exhaustive study in glazes and enamels and what he does not know along these lines up to the present time is not worth knowing. His lecturing tours on clay working and ceramics have extended from the Atlantic to Pacific oceans and from the Gulf of Mexico to our northern clay belt in Canada. But no doubt it will be conceded that these were only stepping stones to greater things as General Secretary of the AMERICAN CERAMIC SOCIETY. Taking hold of this institution when at a low ebb he has been instrumental in increasing its membership to thousands and extending its scope of work until today there is scarcely a manufacturing plant of any description in the United States or Canada that has not become more efficient because it is in close touch with this great SOCIETY. He has been of wonderful assistance to us here in the founding of a ceramic course at Toronto University and which promises to be a great help to our young men and through them our industries. When you meet this gentleman you meet a real good fellow and to shake his hand is like

coming in contact with an electric current. Why should we not do honor to men of this class? for it is seldom we meet them and when we do we rather envy their congenial spirit and open hearted life. It is my great privilege to ask Mr. Purdy to accept a life membership in the Canada National Clay Products Association from the President and Executive of the same. We trust he may be long spared to enjoy it and his association with us here which we prize above all else.

CHARLES F. BINNS MEDAL

On the completion of the twenty-fifth year of Charles Fergus Binns as Director of the Ceramic School at Alfred, the Alumni of the school were pleased to found this medal in commemoration. Two conditions were laid down, first, that the medal should be awarded annually for high achievement in ceramic art and, second, that it should be designed by Miss Elsie Binns, eldest daughter of Dr. Binns.

The selection of the Jury was very carefully considered in consultation with some of those interested, and it was decided to form a Jury of five persons who should represent as far as possible nation wide interests. The Jury was finally composed of:

The Director of the School of Ceramics at Alfred, Chairman, Charles F. Binns.

One member appointed by the AMERICAN CERAMIC SOCIETY, Paul E. Cox.

One member appointed by the National Terra Cotta Society, H. J. Lucas.

One member appointed by the United States Potter's Association, T. B. Anderson.

One member appointed by the Ceramic Guild of Alfred, Miss Ruth E. Canfield.

For the year 1926 the medal has been awarded to Miss Marion L. Fosdick, Professor of Modeling and Pottery at the Alfred Ceramic School.

Miss Fosdick has loyally worked for the school under difficulties and discouragement and her influence has spread, literally, from Massachusetts to California and from Illinois to Alabama.

Miss Fosdick has mastered the intricate arts connected with the production of decorative pottery and in addition to imparting instruction to a large number of students has herself produced some notable pieces of work.

In the Art Division of the SOCIETY she has been active and during the past year she has abstracted all the contributions bearing upon ceramic art which have appeared in the *Transactions* and the *Journal*.

CALENDAR OF CONVENTIONS

AMERICAN CERAMIC SOCIETY		
Annual Meeting	Feb., 1928	Atlantic City, N. J.
American Chemical Society	April 11–16, 1927	Richmond, Va.
Amer. Electrotechnical Soc.	April 28–30, 1927	Philadelphia, Pa.
Amer. Foundrymen's Assn.	June 6–9, 1927	Chicago, Ill.
Amer. Gas Association	Oct. 10, 1927	Chicago, Ill.
Amer. Inst. Chem. Engrs.	June 1–4, 1927	Cleveland, Ohio.
Amer. Soc. Mech. Engrs.	May 23–26, 1927	White Sulphur Springs, W. Va.
Amer. Soc. Steel Treating	Sept. 19–23, 1927	Detroit, Mich.
Amer. Soc. Testing Materials	June 20–24, 1927	French Lick, Ind.
Amer. Zinc Institute	April 18–19, 1927	Montreal, Canada.
Assn. Chem. Equipment Mfrs.	Sept., 1927	New York City
Exposition of Chem. Industries	Sept. 26–Oct. 1, 1927	New York City
Glass Container Assn.	April or May, 1927	?
Manufacturing Chemists Assn.	June 2, 1927	New York City

Natl. Academy of Sciences	April 25–27, 1927	Washington, D. C.
Natl. Assn. of Mfrs. of Pressed and Blown Glassware	March 8, 1927	Pittsburgh, Pa.
Natl. Assn. of Stove Mfrs.	May 11–12, 1927	New York City
Natl. Safety Council	Sept. 26–30, 1927	Chicago, Ill.
Natural Gas Assn. of Amer.	May 17–19, 1927	Cincinnati, Ohio.
Stained Glass Assn. of Amer.	June 27, 1927	St. Louis, Mo.

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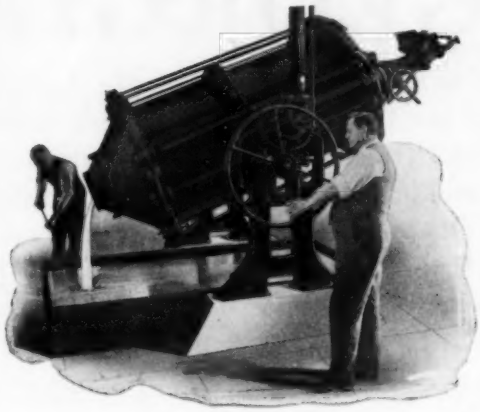

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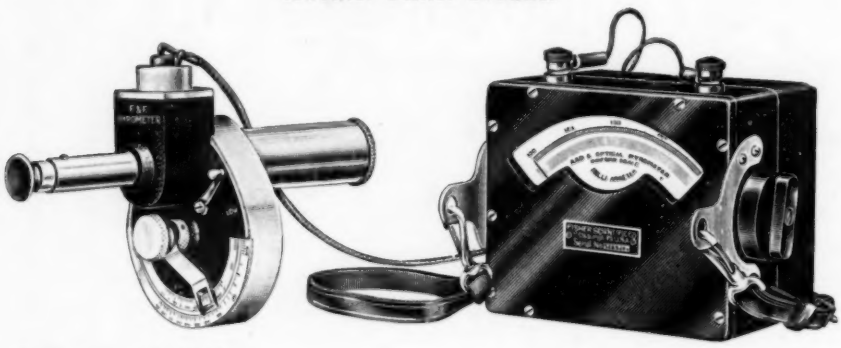

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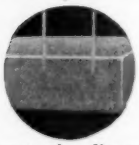

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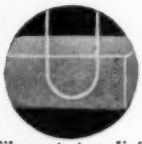

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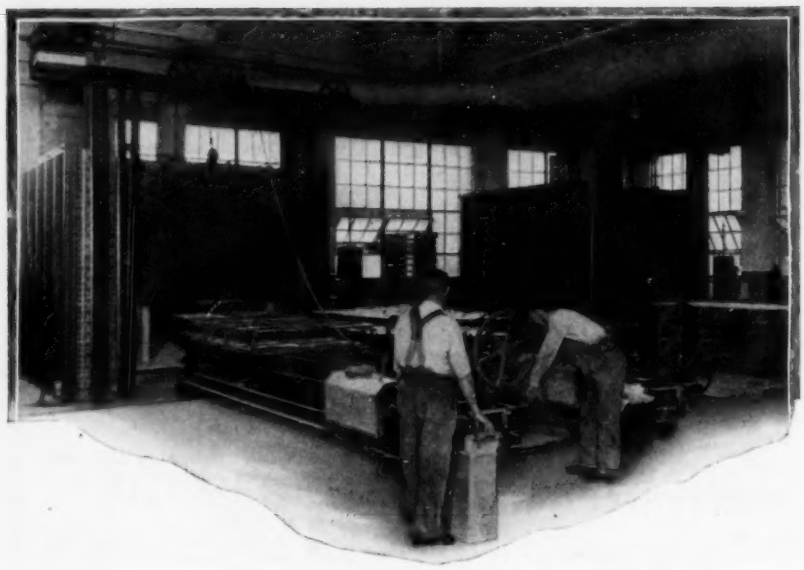

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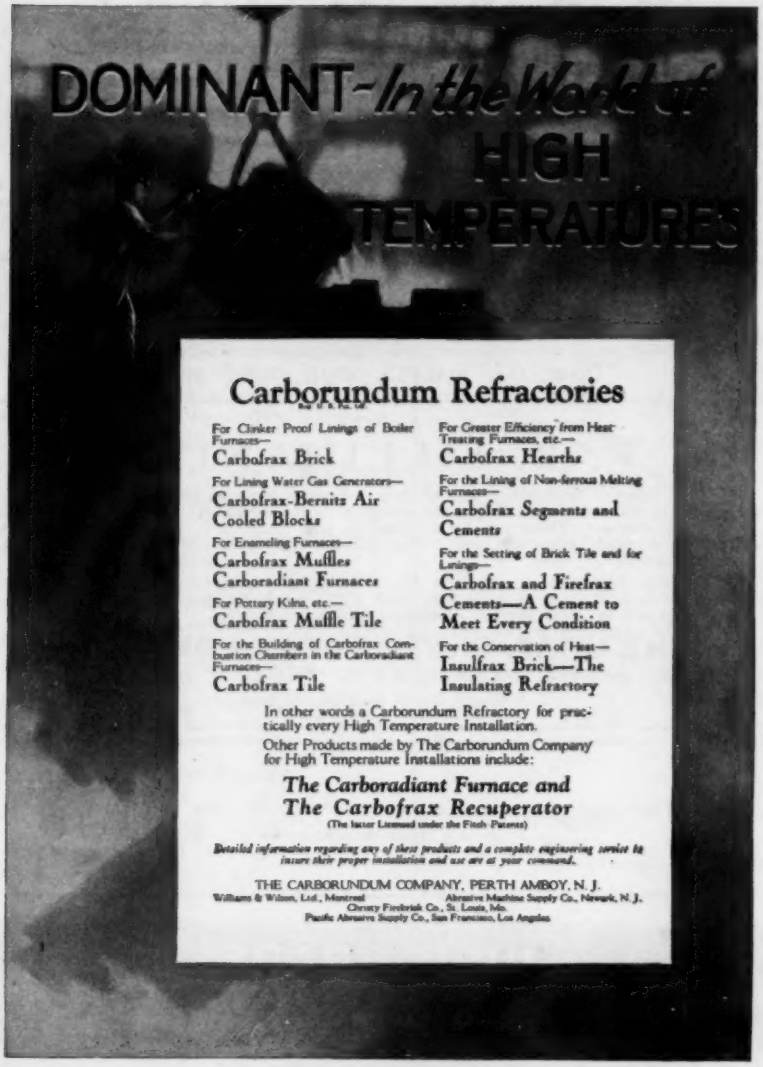

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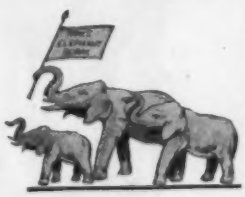

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Crushers Grinders Mixers
Automatic Cutters
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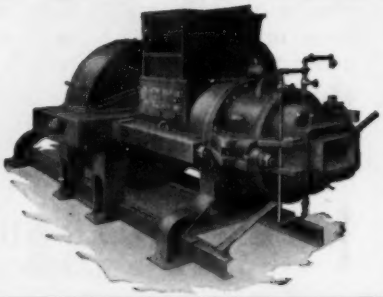
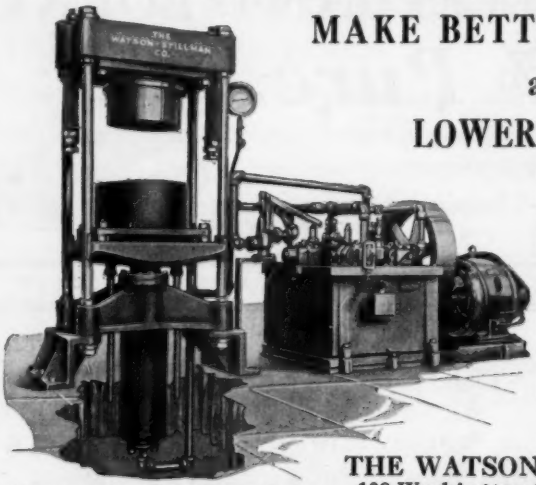
Philadelphia Pennsylvania



WATSON-STILLMAN SAGGER PRESSES
MAKE BETTER SAGGERS
at
LOWER COST



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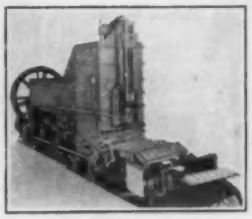

The Arnold-Creager Horizontal AutoBrik Machine, with its fully automatic features and high speed production, is a profit-maker for the fire brick manufacturer. This machine is capable of turning out different shapes and sizes of fire brick due to adjustable press box and table—an exclusive feature. It eliminates hand-bumping and dumping, requiring but two men to operate it successfully. It permits a wider use of clays and reduces waste in the dryers and kilns. It improves quality, producing smooth-faced, square-cornered brick. The 42" Fire Brick Special AutoBrick Machine, with either inside or outside press box, spur or bevel gear drive, will produce 7,000 standard or special shape fire brick per hour with six brick per mould.

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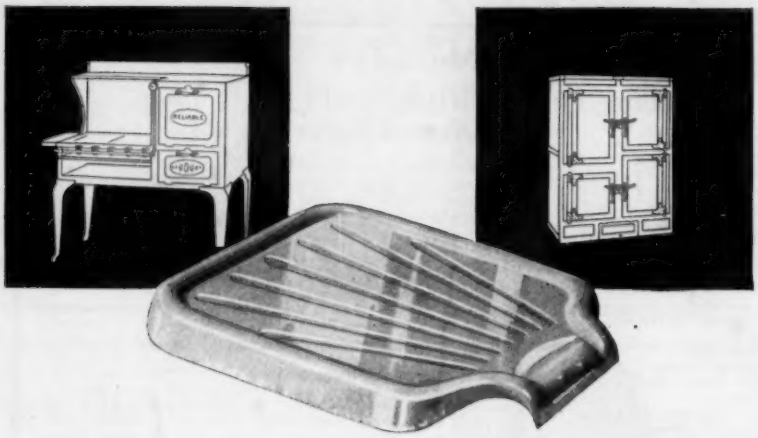

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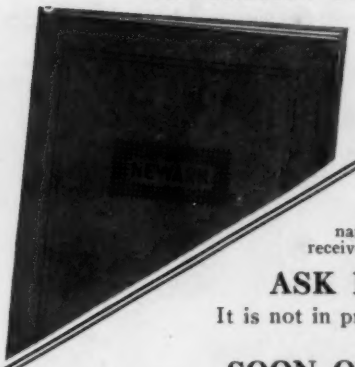

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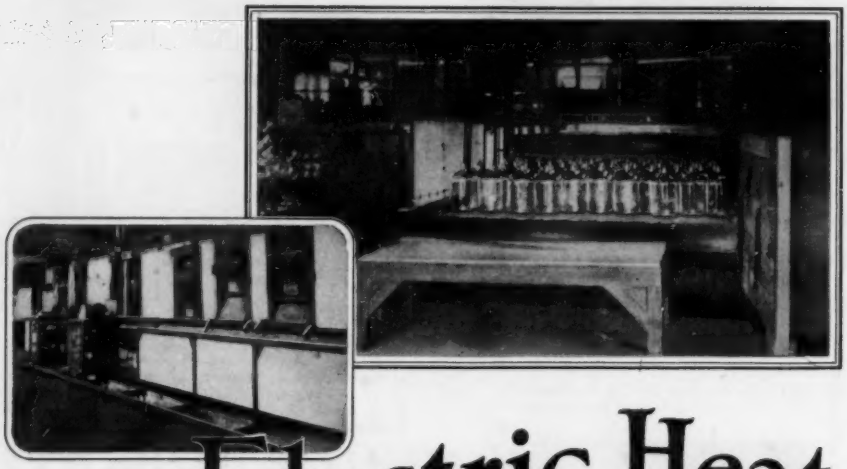

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